CHALMERS
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Bridging Sustainability and Buildability in Infrastructure Projects

Organisation and Sustainability Assessment in Bridge Engineering

Master's thesis in the Master's Programmes Design and Construction Project Management & Structural Engineering and Building Technology

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Division of Construction Management
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Master's thesis ACEX30

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ABSTRACT

There is an increasing need for dealing with all aspects of sustainability in combination with buildability within the infrastructure sector, demanding each actor to take responsibility. The infrastructure construction process tends to be complicated due to many actors involved, with separated goals and aims. The actors have to understand the vitality of their possibility to impact, and the importance of collaboration. This Master's thesis has been conducted to investigate the views on roles and responsibilities concerning sustainability and buildability within the Swedish infrastructure sector, focusing on bridge engineering and early design phases.

The research area is rather complex, and the research questions strive to cover the fundamentals of the subject, constituting the basis for further investigation. The purpose of this study is to map the Swedish infrastructure sector based on the current views of six interviewees from the largest actors in Swedish infrastructure. The interviewees are members of the top project management and represent two of the largest contracting companies, the most extensive public client of civil engineering works, one of the largest consultancy firms, and a material supplier company. The focus has been on getting the top project management's current view of the infrastructure sector concerning roles and responsibilities regarding buildability and sustainability.

The study has shown that collaboration constitutes a base for change, where the infrastructure sector requires a better trans-boundary understanding of the actor's responsibilities. The top project management emphasizes the weight of cooperation for improving the work with sustainability and buildability in infrastructure projects. Concerning this, a work plan that provides a concept for the execution of different project delivery methods could help harmonise the industry and potentially facilitate sustainability and buildability. Further, it could also enhance collaborative working methods, which the top project management encourages. Sustainability performance assessment is of great value for improving the sustainability work in the infrastructure sector. An improvement, desired by the interviewees, is a tool that includes several aspects of sustainability to make profound sustainability assessments in the projects. The economic aspect of sustainability is, in our opinion, found as the most prominent driving force for change, and constitutes the base for creating financial incentives, which the top project management seems to encourage.

Keywords: Sustainability, buildability, early design phase, roles, responsibilities, work plan and infrastructure sector.

Förena hållbarhet och byggbarhet i infrastrukturprojekt
Organisation och hållbarhetsutvärdering inom brokonstruktion
Examensarbete inom mastersprogrammen Organisering och Ledning i Bygg- och Fastighetssektorn & Konstruktionsteknik och Byggnadsteknologi
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SAMMANFATTNING

Det finns ett ökande behov av att hantera alla aspekter av hållbarhet i kombination med byggbarhet inom infrastruktursektorn, vilket kräver att varje aktör tar sitt ansvar. Infrastrukturbyggnadsprocessen tenderar att vara ganska komplicerad då den innefattar många aktörer, med separata mål och syften. Aktörerna måste förstå vitaliteten i deras möjlighet att påverka så väl som vikten av att samarbeta. Detta examensarbete har genomförts för att undersöka synen på roller och ansvar kring hållbarhet och byggbarhet inom den svenska infrastruktursektorn idag, med fokus på brokonstruktion och tidiga designfaser.

Forskningsområdet är ganska komplicerat och forskningsfrågorna strävar efter att täcka ämnets grundläggande faktorer samt utgör grunden för vidare utredning av ämnet. Syftet med denna studie är att kartlägga den svenska infrastruktursektorn baserat på den aktuella synen på ämnet som de sex intervjuade personer från de största aktörerna inom svensk infrastruktur har. De intervjuade kommer från den högsta projektledningen inom företagen och representerar två av de största entreprenadföretagen, den största offentliga kunden av infrastruktur, ett av de största konsultföretagen samt ett materialleverantörsföretag. Fokus har varit på att få den högsta projektledningens aktuella syn på infrastruktursektorn vad det gäller roller och ansvar för byggbarhet och hållbarhet.

Studien har visat att samarbete utgör en bas för förändring, där infrastruktursektorn kräver en bättre gränsöverskridande förståelse av varje aktörs ansvar. Den högsta projektledningen betonar vikten av samarbete för att förbättra arbetet med avseende på hållbarhet och byggbarhet i infrastrukturprojekt. En arbetsplan som tillhandahåller ett koncept för genomförande av olika projektleveransmetoder kan gällande detta hjälpa till att harmonisera branschen och potentiellt underlätta arbetet med hållbarhet och byggbarhet samt gynna samarbete. Vidare kan en arbetsplan även stödja samarbetsmetoder, vilket är något som den högsta projektledningen vill främja. Utvärdering av hållbarhetsprestanda är av stort värde för att förbättra hållbarhetsarbetet inom infrastruktursektorn. En förbättring, som önskas av de intervjuade, är ett verktyg som innehåller flera aspekter av hållbarhet för att kunna göra djupgående hållbarhetsbedömningar i projekten. Den ekonomiska aspekten av hållbarhet anses, enligt vår uppfattning, vara den mest framstående drivkraften för förändring och utgör basen för att skapa finansiella incitament, vilket den högsta projektledningen ställer sig positiv till.

Nyckelord: Hållbarhet, byggbarhet, tidiga skeden, roller, ansvar, arbetsplan och infrastruktursektorn.

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PREFACE

This Master's thesis has been conducted as a combination of the two divisions Construction Management and Structural Engineering at the Department of Architecture and Civil Engineering at Chalmers University of Technology, Sweden. The thesis is a part of the Master's Programmes Design and Construction Project Management and Structural Engineering and Building Technology and was carried out during the period between January and June 2020, composing a total of 30 ECTS.

First and foremost, we would like to thank our examiners and supervisors, Christian Koch and Rasmus Rempling, at the division's of Construction Management and Structural Engineering, respectively, who have supported us with their profound expertise, contributing with inestimable help which has resulted in a thoroughly executed Master's thesis. We want to address a thank to our supervisor Mats Karlsson, Professor of the Practice at the Department of Architecture and Civil Engineering, for assisting with his long experience of civil engineering works, helping us to improve the thesis. Further, we would like to thank the interviewees for their willingness to contribute with their time and knowledge. Your expertise has enabled the conduction of this Master's thesis.

The Master's thesis constitutes the final part of our education at Chalmers University of Technology. It has been intriguing to study a field of construction management almost entirely new to us, and it has widened our view of the construction industry. In conclusion, we would like to thank all of you who have helped us in carrying out this thesis.

Göteborg, May 2020

Alicia Linderfalk
Sofie Ljungqvist

Acronyms

AIA The American Institute of Architects. v, 3, 10, 12, 20, 36

CIRIA Construction Industry Research Information Association. 16

DB Design-Build. 14, 23, 35, 36, 41

DBB Design-Bid-Build. 14, 15

ECI Early Contractor Involvement. 15, 23, 26, 35, 36, 41

IABSE International Association for Bridge and Structural Engineering. 3

IPD Integrated Project Delivery. v, 12, 13, 15, 36

LCA Life Cycle Assessment. 17, 29

LCC Life Cycle Cost. 17, 18, 21–23, 29, 34

MCDA Multi-criteria Decision Analysis. 18, 19

RIBA Royal Institute of British Architects. v, 3, 10–12, 20, 36, 38

STA Swedish Transport Administration. 13, 18, 19, 22, 23, 25, 27–29, 31, 33–36, 38

1 Introduction

In the infrastructure sector, it is common that projects become big and complex, with many actors involved (af Hällström & Bosch-Sijtsema, 2019). The more actors involved, the more ways of carrying out activities are to coexist, leading to a process characterised by differences and potential sources of conflicts. Concerning this, poor use of available knowledge might be a fact, leading to wasteful use of resources and thus decreased sustainability and buildability. It is vital to find working methods that make this possible to get a construction process that is as efficient as possible.

By the construction industry being such a significant pollutant, there is a need to steer the industry towards sustainability. However, there is more to the term sustainability than carbon dioxide emissions since the concept constitutes of the three aspects; economic, environmental, and social sustainability. Dhahri and Omri (2018) stresses that the three pillars of sustainability are equally important and must coexist. Although, there is a tendency that the economic aspect is somewhat the catalyst for the other elements. When defining sustainable construction, it is essential to include that the process ensures consideration of all issues of sustainability as well as the whole life-cycle (Bueno et al., 2015). It is necessary with sustainable use of resources and to reach that, business models, as well as, behaviours have to be changed (EuropeanCommission, 2015b).

The need for dealing with environmental and economic sustainability in combination with increased productivity and buildability has created a demand for innovative structural design methods. For that reason, it is of significant importance to design and build smarter, where the actors in the infrastructure sector could benefit from enhanced collaboration. It is in the early design phases the specialists at each area has the opportunity to influence the project outcomes; such as cost structure, risk management, time-schedule and the collaboration between contractor and client (Laryea & Watermeyer, 2016). A thorough understanding of the early stages creates the fundamentals for establishing the design and can also result in minimising the waste (Ekström, 2019).

1.1 Background

For realising the importance of including sustainability and buildability in the construction process, it is essential to have a thorough understanding of how the process is carried out, from the earliest phases to post-production. It is necessary to understand the complete process, for, in that way, seeing the vitality of including change in the earliest of stages. The construction process can be defined in different ways and includes various stages depending on if it is in the building or infrastructure sector. A common form of identifying the stages of the infrastructure construction process starts with a feasibility study followed by planning approval and procurement. As a parallel process to the planning approval, the conceptual design and preliminary design take place, see Figure 1.1. After this, the detailed design stage starts, proceeding with the construction stage followed by maintenance, during the period of usage, and ends up in the demolition of the object (Ekström, 2019; Scanlon & Davis, 2011). Studying this chain of activities, Ekström (2019) subdivides these activities into three main categories; pre-construction, construction, and post-construction.

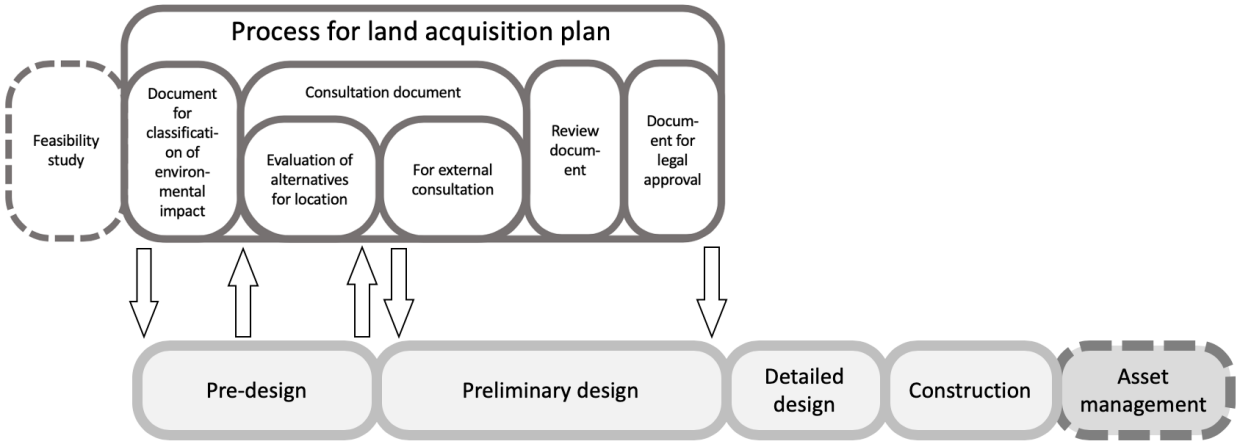


Figure 1.1: Illustration of the steps in the construction process for civil engineering works, developed with inspiration from Trafikverket (2020).

In the stage of pre-construction, the main task is to create a design solution that meets all the demands and requirements that the client has specified. The stage is limited to the competences available and connects to the early phases of the construction process (Ekström, 2019). Thus it is essential to, advantageously and efficiently, corporate these to create an outcome design that is as satisfactory as possible for the client. The design solution, concerning structural engineering, should besides the client's needs, be sustainable in the long run, which includes being durable, having a low cost as well as a satisfactory life-cycle design (Ekström, 2019).

In the earliest stages, it is primarily the decision-makers on higher levels within the organisations that are the source of influence. The construction industry consists mainly of projects where the organisations connect to specific projects (Löwstedt et al., 2018). In the creation of strategic project capabilities, the project and the organisation are two levels that integrate learning with each other, where the knowledge can transfer in ascending parts of the organisation. The infrastructure projects can be seen as a management regime, with the top project management being the most influential group. The top project managers are the most influential group in an organisation, and they will aim to form the organisation and its structure in such a way that their interest and values are reflected in it (Clark & Soulsby, 2007). Clark and Soulsby (2007) opines that the ideas and values of the top project management mirror on the culture of the organisation at hand.

There are different ways to work towards a more sustainable and buildable construction process, where the project delivery method is essential for delivering a project that goes in line with its aim. Different project delivery methods promote different ways of executing a project, where various sample documents are followed depending on which project delivery method that uses. There exist both international and national sample documents, quite similar to each other. The sample documents provide templates for how to stipulate legal contracts between the involved actors in the construction projects. In parallel, there exist work plans that offer guidelines, rather than straightforward demands, for how to execute a construction project.

In contrast to the sample documents that exist within the project delivery methods, the work plans provide an overview of the whole process, without being legally binding. Work plans and guidelines exist both within the infrastructure sector and the building sector. However, the guidelines that exist within the infrastructure are closed and connected to specific organisations. Concerning this, the building sector has come further than the infrastructure sector, with several institutions providing

scientifically developed guidelines. Examples of such institutions are The American Institute of Architects (AIA) and Royal Institute of British Architects (RIBA), which strives to create general guidelines to get a more uniform construction process that enhances sustainability, buildability, and efficiency. There is an interest in investigating the need and responsiveness of the Swedish Infrastructure sector to establish general work plans similar to the ones that are provided within the building sector, for, in that way, work towards a sustainable and buildable infrastructure construction process.

1.2 Purpose

The purpose of this study is to investigate the view on roles and responsibilities with respect to sustainability and buildability within the Swedish infrastructure sector today, with a focus on bridge engineering and early design phases. The study is part of an ongoing Task Group within the International Association for Bridge and Structural Engineering (IABSE), called "Sustainability driven bridge engineering for early design phases".

1.2.1 Research Questions

To reach the purpose of the study, following Research Questions (RQ) are stated:

1. What is the view of the top project management on their role and responsibility concerning both buildable and sustainable infrastructures?
2. Which aspect of sustainability is particularly essential for driving sustainability work?
3. Are there working methods and tools that facilitate sustainable thinking in the early design phase of the infrastructure construction process?
4. Can existing work plans for the construction process within the building sector be the basis for similar guidelines for the infrastructure sector?

1.3 Scope and Limitations

This thesis addresses the roles and responsibilities in the early design phases of the Swedish infrastructure construction process, concerning sustainability and buildability. The study's focus will be on the early design phases, to see which impact these have on the infrastructure construction process. International work plans within the building sector will be studied due to insufficiently developed work plans within the infrastructure sector, to enable a comparison between existing work plans and the mapping obtained in this study. Regarding the definition of sustainability, this thesis will have its basis in the economic aspect to see if economic sustainability potentially is the driving force for working with sustainability and buildability within the infrastructure sector.

Since the study is looking into roles and responsibilities, the interviewees considered are those within the top project management of the organisations. Since the area of research is rather abstract and complex, it requires interviewees with much knowledge and expertise within the field. To slowly changing the infrastructure sector to integrate sustainability and buildability in the construction processes, the top project management is the starting point for the change.

1.4 Thesis Outline

The study constitutes six chapters, structured in a way that gradually builds up the knowledge of the reader at the same time as it follows the design of the research process. The order and the content of each chapter are as follows;

Chapter 1 - *Introduction*

In this chapter, the aim and purpose of the study are presented, together with an introduction that gives the reader a clear presentation of the work.

Chapter 2 - *Research Methodology*

The Research Methodology describes the research process and what methods used to conduct the study. This chapter includes an analysis of the reliability and validity, as well as the ethical impacts of the study.

Chapter 3 - *Theoretical Framework*

In the Theoretical Framework, the underlying theory for the study is presented to give the reader sufficient knowledge of the subject for assimilating the analysis, discussion and the conclusion presented further on.

Chapter 4 - *Empirical study*

In this chapter, the empirical findings from the interviews are presented. Together with the Theoretical Framework, the Empirical study constitutes the basis for the analysis.

Chapter 5 - *Analysis*

An analysis of the Theoretical Framework and the Empirical data presents in this chapter, to answer the research questions and to find contradictions as well as agreements.

Chapter 6 - *Discussion*

The discussion chapter aims to mediate the thoughts that the researchers have on the analysis.

Chapter 7 - *Conclusion*

This chapter presents the conclusions of the study developed from the Analysis and the Discussion, including recommendations of further study's.

2 Research Methodology

In this chapter, the methodology used in the thesis for achieving its purpose is both described and motivated. The chapter aims to explain how the study was conducted, as well as why the used methods were chosen.

2.1 Overview of the Research Process

The fundamental idea of this study was introduced and developed together with supervisors at Chalmers University of Technology, during fall 2019. The thesis aim and purpose were, therefore, already established when the study started in January 2020. Preliminary research questions were stated and specified to fit the aim. Subsequently, the literature review could begin, and the work with the theoretical framework was undertaken. As the work proceeded, a full branch of literature emerged, after which; the interviews were held, resulting in the theoretical framework requiring adaptation to support the empirical findings. Afterward, transliterating and summarising the empirical data, the process of analysing this data together with the theoretical framework catalysed. As further knowledge and ideas were found, the research process became iterative, and the research questions, as well as the theoretical framework, were adapted, improved, and complemented. At this stage Figure 2.1, explained in Section 2.2, was developed to give a better understanding of the study's structure. When the comparison between the empirical findings and the theoretical framework was made, the analysis, discussion and conclusion could be completed.

2.2 Qualitative Research Approach

The research approach is crucial for the execution of the study, and it allows for different procedures of work to be used. In a qualitative research approach, the research questions can evolve and deepen as more data is obtained (Flick, 2018; Olsson & Sörensen, 2007). The method aims to, by systematise knowledge, characterise the phenomenon at hand (Olsson & Sörensen, 2007). Since this study aims to examine how a certain area of knowledge is treated in the industry today, a qualitative approach with qualitative stirring is suitable to use. The qualitative research approach aims to give an overall understanding of the subject and strives to get an extensive overview of the phenomenon. It is a holistic approach, originated from the broad perspective of a subject aiming to include its all parts to get an absolute understanding of it (Olsson & Sörensen, 2007). In qualitative research, the theory is not the base of the research, enabling data collection; instead, the theory can be developed together with new findings throughout the data collection (Bryman & Bell, 2015). In this research, the considered method for data collection is by semi-structured interviews. After each interview, extensive work with analysing the data has been carried out, to seek for new and relevant key subjects to consider in the theoretical framework. Bryman and Bell (2015) supports this, who states that one key point of the qualitative research approach is "the typical sequence of steps in qualitative research entails the generation of theories rather than the testing of theories that are specified at the outset" (p.398). In Figure 2.1 the main steps of the research method is illustrated with inspiration from Bryman and Bell (2015).

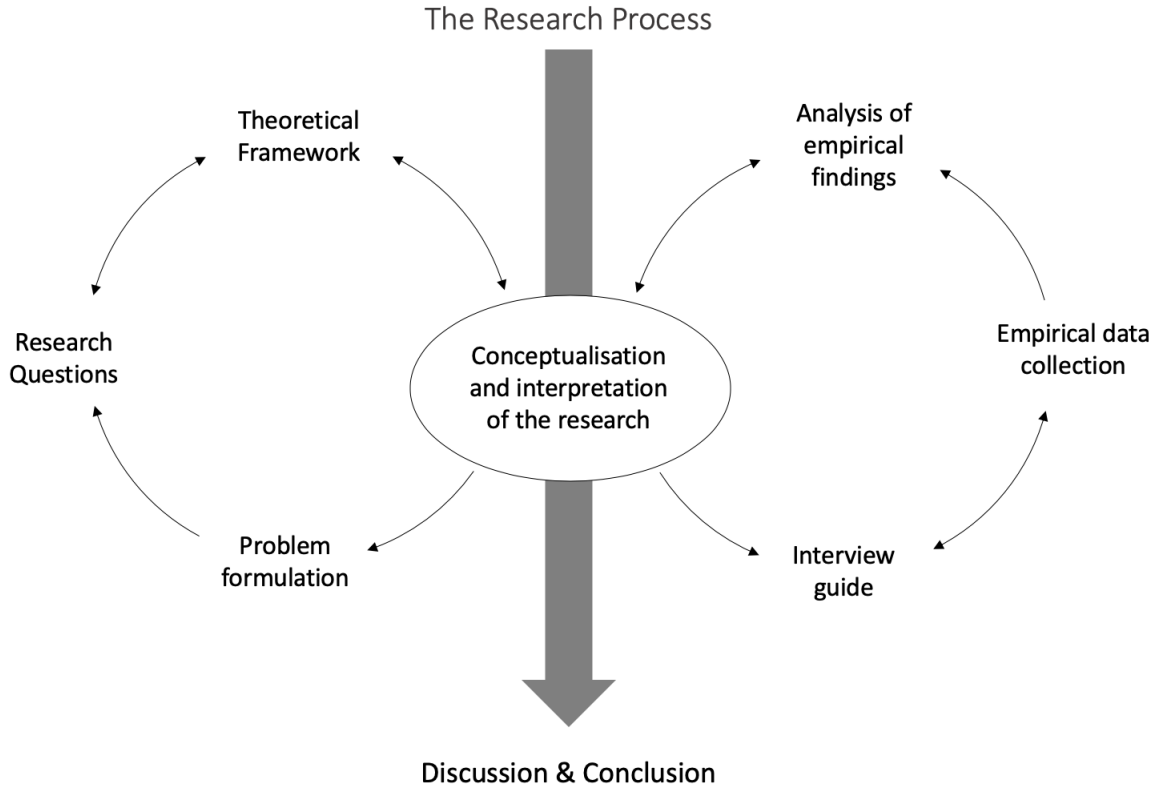


Figure 2.1: An overview of the qualitative research approach that is used in the study.

The qualitative approach of the study started with formulating a basic concept and research questions of the study, where we, as researches, used our interpretation of the subject to start the work with the theoretical framework. By using qualitative stirring such as an interview study, the thesis grew by improving the literature with findings from the interviews. In that way, the research questions were developed.

The research process is iterative, where the hypothesis and the content of the study rise as more data are collected, enabled by using a qualitative research approach (Bryman & Bell, 2015; Flick, 2018). As a result of a qualitative research approach having its foundation in desisting from establishing a correct and theoretical hypothesis, it instead enables improvement of them by using iterative analysing methods of the collected data together with the theoretical framework (Flick, 2018).

2.3 Abduction

By the thesis being a qualitative study, the work is iterative, and the collected data is compared continuously with the theoretical framework to enhance its quality and reliability. Abductive reasoning is a method to create new ideas as the research proceeds (Johansson, 2002). It is motivated to use abductive reasoning when necessary to overcome the limitations often met by using inductive or abductive theory (Bryman & Bell, 2015). By using abductive reasoning, it is enabled to go back-and-forth between the empirical findings and the theoretical base to seek for new conditions among them, which means that the theoretical framework develops as potential discoveries and essential aspects of the theory are obtained from the interviews (Bryman & Bell, 2015). The abductive reasoning requires an interplay between the different parts of the research; it is characterized by having an

inconclusive theoretical background, and to be driven forward by the desire to create the purpose of this (Johansson, 2002).

2.4 Literature Research

To be able to carry out a mapping of how the infrastructure sector is handling roles and responsibilities concerning sustainability and buildability today, literature research regarding the area was done to identify standard definitions as well as distinctive theories and concepts. Literature references were found by searching databases such as Google Scholar, SAGE, and Scopus, where different combinations of keywords have been used. Some of the keywords used in the search were sustainability, buildability, construction process, early design phase, roles in construction and collaborative methods. English literature was mainly considered during the research, but since the study is carried out in Sweden and is regarding the Swedish infrastructure sector, also some literature in Swedish was of relevance. Furthermore, the number of citations, as well as publication dates, were also taken into consideration when choosing the literature. As mentioned before, the research process of the study is iterative, which in turn resulted in that complemented research were made as the work proceeded.

2.5 Empirical Data Collection

The purpose of a qualitative approach is to understand the research aim from the perspective of the interviewees, throughout an everyday situation (Kvale & Brinkmann, 2014). The interview study was conducted with representatives from two of the largest Swedish contracting companies, the most extensive public client of infrastructure works in Sweden, one of the largest consultancy firms, as well as a material supplier company, resulting in a total of six interviews, see Table 2.1. All interviews were carried out in Gothenburg, with two of them being phone interviews. The base for the interviews is a semi-structured interview guide, where the questions were prepared prior to the interview occasion. However, the qualitative interview structure allows for the issues to develop as the interview proceeds, and the interviewee also has the opportunity to advance their answers (Lantz, 2007).

Table 2.1: Information about the interviewees.

Actor	**Interview type**	**Date**
Client#1	In person	14/2/2020
Client#2	Phone interview	10/3/2020
Contractor#1	In person	25/2/2020
Contractor#2	In person	28/2/2020
Structural Engineer#1	In person	5/3/2020
Material Supplier#1	Phone interview	18/3/2020

All the interviewees are kept anonymous in the study to encourage as much honesty as possible. The interviews were conducted for around 60 minutes, and the physical interviews took place at the interviewee's places of work. For not missing out on relevant information from the interviews, they were recorded and transliterated afterwards. The selection of interviewees was made in consultation with our supervisors. Since the study is treating a delicate subject with limited previous research, it was crucial to choose interviewees with the right knowledge and experience. The interviewees are experienced in civil engineering works and selected as their roles are within the top project management in the infrastructure sector.

2.6 Analysis techniques

Based on the choice of using a qualitative research approach, the analysis and coding of the empirical data were made according to the method thematic analysis. The process of a thematic analysis consists of a constant going back-and-forth between theory, empirical data, and the coding themes (Braun & Clarke, 2006). The process developed over time and is not linear, that is when in the process is moving from one phase to the other. Thematic analysis method does not always need to wed to any pre-existing theoretical framework.

Thematic analysis is based on the means of dividing the data into different themes and sub-themes. Themes should be closely related to the aim and purpose of the research, as well as relate to the study's theoretical base, providing the researcher knowledge and understanding of the data, for improving the theory (Bryman & Bell, 2015). In a qualitative study, which is based on interviews as the source of empirical data, it is essential to transliterate the interviews. By transliterating the interviews, the work of finding themes to use in coding and analysis is simplified. Braun and Clarke (2006) states that the first phase of thematic analysis is to acquaint yourself with the data and that transliteration is one approach to this. After transliterating the interviews, the work of finding themes and sub-themes began. In order to systematize the work, the four themes *Early Phases*, *Sustainability*, *Buildability* and *Responsibilities* were decided upon to look for when reading the transcripts. These themes were, later on, developed into *Economy*, *Early Phases*, *Roles and Responsibilities* and *Tools and Driving forces*, to code the findings, a research approach supported by Bryman and Bell (2015). It is important to have in mind that a theme could be many things and be of various importance (Braun & Clarke, 2006). The nature of thematic analysis allows for the flexibility of identifying, analyzing, and mapping how the infrastructure sector is working today concerning roles and responsibilities regarding sustainability and buildability.

Overall, it is essential to emphasize the active role that the researchers play in forming the thematic analysis. When carrying out a project, the researcher's viewpoint will mirror in the study, as well as the angle of aggressing the topics in the research and identifying themes in transcripts (Braun & Clarke, 2006). Braun and Clarke (2006) underlines this and states "What is important is that the theoretical framework and methods match what the researcher wants to know, and that they acknowledge these decisions, and recognize them as decisions" (p.82).

2.7 Ethics

A study based on interviews could bring on potential ethical issues. For avoiding any misunderstandings, the interviewees were informed about the scope of the study before the meeting. It was of interest, from a moral point of view, to notify the interviewees of what their role and contribution to

the study were to be. The interviewees were asked beforehand if a recording of the meeting could be performed. For creating connective research, the interviewees were kept anonymous. By doing so, it possibly encouraged the interviewees to speak open-minded and freely during the conversation without worrying that their statement would affect them afterwards. Furthermore, close collaboration with supervisors at Chalmers was carried out continuously, which was a vital part to ensure that the project always was in-line with its purpose.

2.8 Trustworthiness

It is essential to describe how the collection of material has developed during the research process, to give the study validity and reliability (Malterud, 2014). Validation means that the study measures what is relevant in the context, while reliability means that the study measures it reliably. High reliability is no guarantee for high validity, but a high validity requires a high degree of reliability (Malterud, 2014).

Trustworthiness constitutes of the four aspects; credibility, transferability, dependability, and confirmability (Malterud, 2014). Credibility shows how trustworthy the data collection and the results are. When selecting the interviewees, the aim was to ensure the inclusion of all main roles in the infrastructure construction process, to consider a comprehensive perspective. This technique is called source triangulation and gives the study higher trustworthiness. All interviewees were able to take part in the findings of the study to ensure that their answer was correctly interpreted, conducted to reach the respondent validation (Bryman & Bell, 2015). During the analysis of the empirical data collection, different paradigms were used to contribute to a theory triangulation, which reinforces the validation in the study.

Furthermore, a high level of transferability was accomplished by assessing how the results could apply in the future. The interviews were recorded with two recorders to ensure that everything was collected and to achieve high dependability in the study. Throughout the process of developing the material, the content was constructed objectively without including personal values of the findings, to make high confirmability of the study.

3 Theoretical Framework

This study's theoretical framework aims to give a thorough knowledge base for interpreting the empirical data collection that is presented later on. The study has its fundamentals in looking at existing international construction work plans. However, only international construction work plans exist for the building sector and not for the infrastructure sector. Since there is much to learn from the guidelines in the building sector, the study presents them. The theoretical framework proceeds with offering other subjects of interest for the problem formulation, such as main roles in infrastructure projects, different project delivery methods, and core definitions of both sustainability and buildability.

3.1 International Work Plans within the Building Sector

Royal Institute of British Architects (RIBA) and The American Institute of Architects (AIA) are two architectural institutions from the UK and USA, respectively, which provides two separate and conventional work plans for the construction process concerning the building sector.

3.1.1 RIBA Plan of Work

The Royal Institute of British Architects provides an established work plan for how to manage and organise the whole process of construction projects within the building sector, from early planning stages to handing over and use of the building. The framework is called RIBA Plan of work and is built up by eight stages, which in turn evaluates with respect to several task bars (Rempling et al., 2019; RIBA, 2020). The RIBA Plan of Work applies for all different procurement routes, project sizes and can be used by all actors participating in the construction process (RIBA, 2013, 2020). RIBA Plan of Work is a non-legal document that only provides guidelines for the project teams to use throughout the processes (RIBA, 2013, 2020). Cited by RIBA (2020) "While the RIBA Plan of Work acts as the basis for professional services or building contracts, it is not intended to be contractual; it does not set out in detail who does what at each stage, nor does it define the detail around the many topics covered in this publication." (p.36).

Which procurement route used in the project is crucial for the activities carried out in the stages of the RIBA Plan of Work, although it does not affect the aims of the guidelines (RIBA, 2020). Since the procurement routes separate from each other regarding when different actors enter the process, see Figure 3.1, the decision making in the process will be affected as well as which requirements that are stated. The size and complexity of the project affect the use of the work plan, for which reason there are no suggestions on how to put up a time scale for the projects. The importance of taking advantage of already finished projects, to improve the work of future projects is emphasized by RIBA, leading to that the last stages of the work plan are the essential (RIBA, 2020).

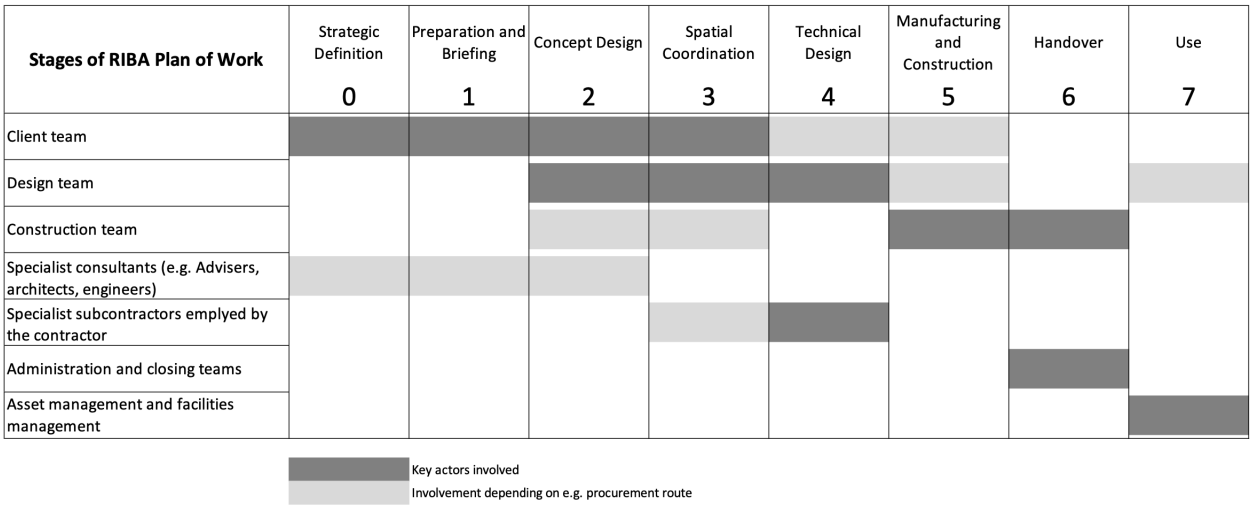


Figure 3.1: Illustration of when different actors can be involved in each stage of RIBA Plan of Work 2020.

Since RIBA Plan of Work is stated as a guideline, the stages are independent of each other. Although they are somewhat constructed to be used together as an entity, leading to that, if one stage is carried out poorly, possible adverse effects can occur on further stages (RIBA, 2020). Each stage of the RIBA Plan of Work is evaluated with respect to several task bars, which provides the key aspects of each stage. The task bars are as follows; Core Task, Core Statutory Processes, Procurement Strategy, Information Exchanges, Project Strategies, Conservation Strategy, Cost Plan Strategy, Fire Safety Strategy, Health and Safety Strategy, Inclusive Design Strategy, Planning Strategy, Plan for Use Strategy and Sustainability Strategy.

To enable for including sustainability in the projects, the task bar Sustainability Strategy is provided in the plan of work. The task bar considers a broad perspective of sustainability and provides a framework with several actions and checkpoints for ensuring that the sustainability requirements from the client and other regulations are met, with some of the checkpoints related specifically to the UK construction industry while some are more general.

When studying the different stages of RIBA Plan of Work, it is possible to see that they can be divide into three different categories similar to the construction process defined in 1.1. Wood (2010) implies that stages 0 and 1 constitutes the feasibility study, stages 2-4 represents the pre-construction period and stages 5-7 makes up the construction period, illustrated in figure Figure 3.2.

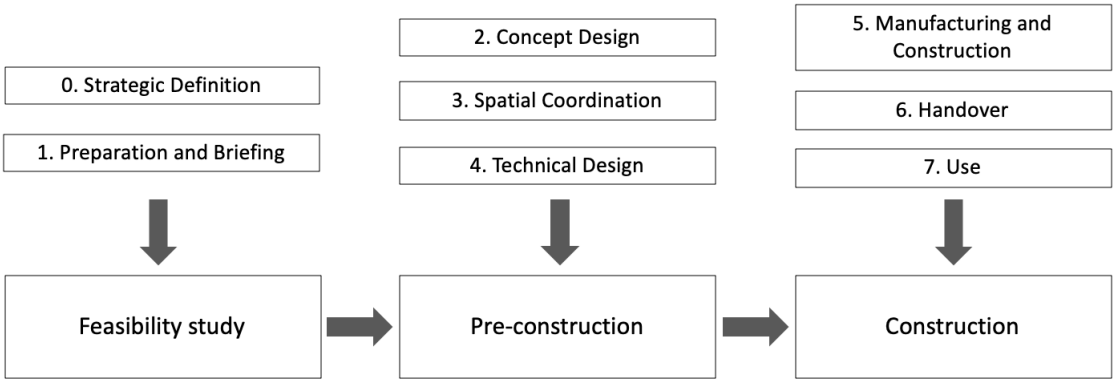
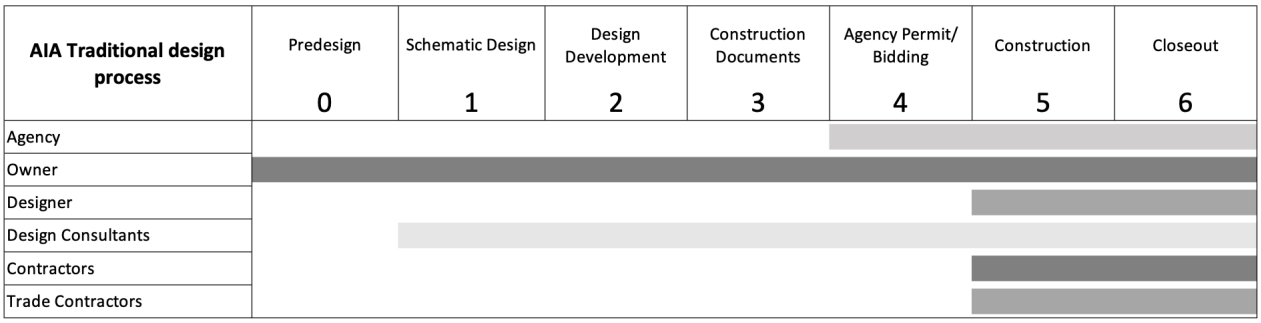


Figure 3.2: The sectioning of the stages in RIBA Plan of Work into the construction phases.

3.1.2 AIA - Integrated Project Delivery

Anumba et al. (2002) list several key disadvantages with the separation of design and construction in the traditional approach of the building sector, where fragmentation of both data and roles in construction as well as hampered life-cycle analysis are some of them. The American Institute of Architects provides a project principle applicable to a wide range of different contractual arrangements called Integrated Project Delivery (IPD). It has its core in collaborative project teams that are integrated with each other and enhances that all team members should be engaged in all parts of the project. AIA (2007) defines IPD as "a project delivery approach that integrates people, system, business structures and practices into a process that collaboratively harnesses the talents and insights of all participant to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction." (p.0). To succeed with IPD, it is essential to build good trust among the included project participants and team members since IPD is built on collaboration and successful collaboration has its base in trust (AIA, 2007).



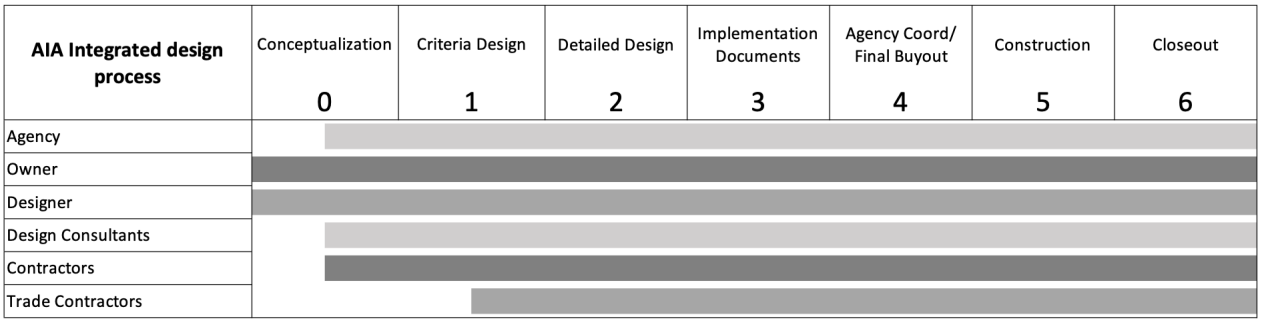


Figure 3.3: Comparison between the traditional method and the IPD method of AIA.

By making it possible for the project participants to be included from an early project start, the different competencies provided in the construction process are utilized efficiently (AIA, 2007). This applies especially to the client, the contractor and the design team since they are the main participants in the project (AIA, 2007). In Figure 3.3, the traditional design process and the IPD process are compared with each other. The IPD process has redefined some of the phases from the traditional method. The redefinition is driven mainly by the early integration of knowledge from the project participants. The IPD process aims to complete as much as possible in early project stages, which results in smoother work with the stages further on in the design process in comparison to the traditional design process. Overall, IPD provides a process where many tasks are completed and defined in the pre-construction stage, streamlining the construction period (AIA, 2007).

The distribution of responsibility in IPD aims to carry out the provided task in the best possible way rather than to separate the tasks between the team members. IPD adapts to the abilities and talents of the participants, the distribution of roles and the goals of the project (AIA, 2007). The roles and task distributions should be clearly defined in the early stages of the project, for eliminating barriers to communication and enhance trust as well as collaboration during the project process. AIA (2007) states that "key to successful Integrated Project Delivery is assembling a team that is committed to collaborative processes and is capable of working together effectively" (p.20).

3.2 Main Roles

Client, structural engineer, contractor, and material supplier are the main roles participating in the infrastructure construction process (AIA, 2007; Ekström, 2019; Koçtaş & Tek, 2013). Collaboration between the involved parties is crucial for carrying out a successful project, including the integration of technology and organisational issues (Puddicombe, 1997). Depending on which project delivery method that is used, the responsibility of the roles varies (Hayati et al., 2019). There are different types of project delivery methods that enhance integration and collaboration to various extent, but the main roles included in the construction process are still the same.

3.2.1 Client

The client is the commissioning entity and is commonly the owner of the project (Koçtaş & Tek, 2013; RIBA, 2020). In Sweden, the largest client of infrastructure projects is the Swedish Transport Administration (STA) (Ekström, 2019). STA is a public authority responsible for the long-term planning, building, maintenance and operation services for public infrastructure regarding all kinds of traffic in Sweden (Trafikverket, 2017, 2019).

3.2.2 Structural Engineer

The structural engineer is a specialist role that provides technical knowledge about the behaviour of the structural system and the structural design (Ekström, 2019). The structural engineer's main task is to design in a way that is economically beneficial, meets the design requirements from the client, and provides a safe and functional structure that uses the material in an efficient way (Luth, 2011). The material is an essential part of the design since it is crucial for the structure's appearance and behaviour. Thus, the structural engineer must possess the right competence to thoroughly understand the behaviour of the material (Ekström, 2019; Luth, 2011). Luth (2011) defines the role of the structural engineer as "an individual who has familiarity with, knowledge of, and appreciation for architectural design and construction means, methods, and sequences and a deep knowledge of

the behavior and performance of engineered systems and who applies this knowledge creatively to develop compatible, safe, functional, economical, and reliable design alternatives" (p.908).

3.2.3 Contractor

The contractor's task is to execute the construction works and to be responsible for the construction site (Ekström, 2019). Depending on which project delivery method used, the contractor also could be liable for the detailed design. Since the construction works is a process where the work of different engineering disciplines comes together. The contractor needs to possess knowledge and understanding about how to connect these instances in a way that is advantageous for the construction works (Luth, 2011). The contractor needs to know how to keep time-schedule, stick to a budget, calculate material use, and possess competence about quality and how to provide good labour (Luth, 2011).

The occurrence of unforeseen events during construction puts pressure on the contractor to solve the issues on site in the best possible way (Tatum, 2011). The contractor must know the fundamentals of each engineering discipline included in the project since that is important for the project's basis, especially when it comes to input on design solutions and to understand the drawings. However, the contractor could hire external consultants to solve specific issues that require more profound knowledge. Although the contractor still needs a basic understanding of technical fundamentals to do this (Tatum, 2011).

3.2.4 Material Supplier

Material supplier is a crucial role in construction, which enters during the construction works as well as during the performance of replacement work (Edum-Fotwe et al., 2001). The material supplier is responsible for delivering construction material, such as concrete and steel (Koçtaş & Tek, 2013).

3.3 Project Delivery Methods

Construction projects can be carried out based on different project delivery methods. In the Swedish Infrastructure sector, the most commonly used method is Design-Build (DB). However, there also exist some collaborative methods which have a base in the project delivery method form Design-Bid-Build (DBB), where the different tasks are divided into different actors.

3.3.1 Design Build

In a Design-Build (DB) contract, the contractor is responsible for carrying out the whole project, including detailed design and construction, after receiving some specifications from the client (Hayati et al., 2019; Potts & Ankrah, 2013). It is a method that enhances the contractor's flexibility in the selection of materials, design and construction works (Gibson & Walewski, 2001). In the beginning, the client identifies some project parameters and performance criteria for the bidder, which are later on developed into a design proposal that optimizes the construction abilities. The contractor with the winning design proposal is announced and assigned, provided with the responsibility to deliver and produce the product. Often when using DB, the scheduled delivery can be done faster, since the construction can start before the detailed design is fully completed as a result of only having one entity responsible for everything (Gibson & Walewski, 2001; Park & Kwak, 2017). By only having one responsible entity, the construction works are enabled to be carried out as smooth as

possible since the contractor can plan for the construction already in the design phase. Because of the contractor being exclusively responsible for the project, the works are almost risk-free for the client (Potts & Ankrah, 2013).

3.3.2 Design Bid Build

Design-Bid-Build (DBB) is a frequently used project delivery method in the construction industry, with its core in the separation of the design and construction phase (Ekström et al., 2019; Gibson & Walewski, 2001; Park & Kwak, 2017; Potts & Ankrah, 2013). The client, therefore, takes on the responsibility to complete the design phase, including contracting engineers. The contractor is then solely responsible for carrying out the design of temporary facilities and hire its subcontractors. The lowest price characterizes the bidding procedure, and it is required that the client has clearly defined the project scope and design, so that the contractor can adequately execute the project (Gibson & Walewski, 2001; Potts & Ankrah, 2013).

3.3.3 Collaborative Methods

In the construction industry, the projects are temporary, and the actors are often put together in new constellations to deliver a product (Hemphill, 2009). Teamwork is nowadays a prerequisite for the successful delivery of projects and because of the many different actors participating in a construction project, many ways of working are to coexist (Ekström et al., 2019). In combination with the changing constellations from project to project, it becomes difficult with learning across project boundaries (Gann & Salter, 2000). With the common short-term perspective in construction, it is always a risk that with poorly managed design coalitions, the construction phase will not perform optimally and could end up as dysfunctional (Forgues & Koskela, 2009).

Infrastructure projects are rather complex, and the actors involved in the projects can have different drivers (af Hällström & Bosch-Sijtsema, 2019). It is in the early design phases the specialists at each area has the opportunity to influence the project outcomes; such as cost structure, risk management, time-schedule and the collaboration between contractor and client (Laryea & Watermeyer, 2016). Partnering, IPD and Early Contractor Involvement (ECI) are three collaborative project delivery methods, gathered under the term “relational contracting”, which according to Ekström (2019) has the aim “to stabilize and formalize the patterns between the client and its suppliers and improve the environment for integrated design team performance” (p.23). These collaborative methods are used to stimulate the trans-boundary collaboration between the actors assigned to the contract, where a trust-based collaboration is needed (Kadefors, 2002). For achieving trust-based collaboration, it is required that all the actors have sufficient competence, mutual goodwill and respect as well as qualities such as reliability and openness (Kadefors, 2002).

A significant benefit of the ECI approach is the nomination of the contractor already in the early phases, before tender. By this, the contractor is enabled to contribute with its expertise already in the planning phase, which in turn leads to improved buildability and cost estimations (Nichols, 2007; Potts & Ankrah, 2013). ECI can be implemented in all construction phases as well as in a diverse set of procurement routes (af Hällström & Bosch-Sijtsema, 2019). By establishing ECI the projects awareness and understanding of the risks become better and also an improved buildability of the design is achieved, contributing to an efficient decision-making process (Eadie & Graham, 2014). Projects with high ratios of complexity, uncertainty and value are more suitable for using ECI than projects with short duration period and low complexity since they need to be more controlled by the client (af Hällström & Bosch-Sijtsema, 2019).

3.4 Sustainability

The most noted definition of sustainability comes from United Nations (1987) and is that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (p.37). Sustainability constitutes three main pillars; social, economic, and environmental sustainability, which are entirely interrelated and must coexist (Dhahri & Omri, 2018). The European Commission states that it is important to change both business models and behaviours so that sustainable use of resources is prioritized (EuropeanCommission, 2015b). Sustainable development needs to be implemented within the resource-consuming activities that burden the environment, and economic incentives should be highlighted, to achieve such thing (EuropeanCommission, 2015b; Næss, 2001). Schaltegger et al. (2012) writes that companies often include sustainability in their business models and by doing that the business can be promoted, possibly resulting in a better reputation on the market (Schaltegger et al., 2012; Van Marrewijk, 2003). Because of the inclusion of sustainability in the business models might turn as profitable, it indicates that there is an economic interest driving the companies (Van Marrewijk, 2003).

United Nations Global Compact (2015) defines Supply Chain Sustainability as "the management of environmental, social and economic impacts and the encouragement of good governance practices, throughout the life-cycles of goods and services. The objective of supply chain sustainability is to create, protect and grow long-term environmental, social and economic value for all stakeholders involved in bringing products and services to market." (p.5). The definition highlights the importance of considering the life-cycles of the products and services. By managing the materials used in construction efficiently throughout the life-cycle, resource efficiency is implemented in the construction process. In 2017, a European Standard was created to provide a framework with principles, requirements and guidelines for how the sustainability assessment of civil engineering works using a life-cycle approach should be carried out (SIS, 2017). The sustainability assessment is formed so that it assesses all parts of sustainability with respect to civil engineering works, and it applies for the whole life-cycle.

The definitions of sustainability tend only to define one of the three pillars at a time (Bueno et al., 2015). When defining sustainable construction, it is essential to include that the process ensures consideration of all aspects of sustainability. Bueno et al. (2015) writes that when defining sustainable infrastructure projects, it is vital to "include the whole life-cycle; from conception through construction, operation, maintenance, and the recycling/reuse stage" (p.625). It is necessary to have the proper infrastructure to make other industries sustainable, at the same time, as it is vital to create sustainable infrastructure (EuropeanCommission, 2015a).

3.5 Buildability

Already in the 1960s, Banwall argued, cited by Griffith and Sidwell (1997), that "design and construction must be considered together and that in traditional construction, the contractor is too far removed from the design stage at which his specialised knowledge and techniques could be put to invaluable use" (p.297). The productivity at a construction site is affected by several factors where buildability is one of the most essential (BCA, 2004; Jarkas, 2010). Buildability is a theory which integrates design and construction and strives to improve the productivity and safety of on-site production while at the same time reducing waste (Jergeas & Put, 2001). The term was established by the Construction Industry Research Information Association (CIRIA) in the UK during the 1970s. At

the same time, in the USA, the term constructability was founded with a similar goal as the term buildability (Simonsson, 2011). What separates the two concepts is that constructability includes management functions, which buildability does not.

The definition of buildability can be found from many different authors but are still quite similar to each other. According to Ferguson (1989), cited by Simonsson (2011), buildability is "the ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and sub-assemblies" (p.17). However, the most commonly cited definition is the one given by Adams (1989), cited by Simonsson (2011) "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building" (p.17).

In the construction industry, projects are often long-term and site-specific with a small number of standardised parts (Nam & Tatum, 1988). Standardising a project as much as possible can give other positive effects for buildability (Simonsson, 2011). Often the contractor in bridge construction projects is divided according to the geographical areas instead of by the different types of bridges. By dividing the projects according to their nature, it allows for repetition of construction and standardisation of production. The contractor will then learn from previous projects, which will ultimately speed up production (Simonsson, 2011). Further, including experts in early design stages for making design decisions, has positive effects on the buildability of the construction project (Jergeas & Put, 2001; Simonsson, 2011; Wong et al., 2006).

3.6 Combining Sustainability and Buildability

Over the years, research has found that bringing in expert knowledge early in the design phases has had positive effects on both buildability and sustainability (Jergeas & Put, 2001; Simonsson, 2011). It is then necessary to apply sustainability assessment tools that allow for the evaluation of choices made in the early design phase.

3.6.1 Life-Cycle Approaches

Life Cycle Assessment (LCA) is a traditional decision-making analytical technique that assesses the environmental impact of a product, process, or activity (Bueno et al., 2015). A complete life-cycle approach is conducted from 'cradle to grave'. It includes an environmental performance assessment consisting of material extraction, transport, manufacturing, product use, distribution, service and maintenance, reuse, recycling, energy recovery and waste handling (Stripple & Erlandsson, 2004). LCA has become a commonly used tool since it provides metrics that can deliver valuable input for sustainability assessment (Baker & Lepech, 2009). Although, LCA fails to incorporate economic, social and environmental sustainability fully as well as having problems that deteriorate the accuracy and makes the results less reliable (Bueno et al., 2015; Loiseau et al., 2012). Cited by Bueno et al. (2015) this is because "its primary purpose is limited to the assessment of the environmental consequences of a given activity" (p.631).

Another analytical approach is Life Cycle Cost (LCC). In contrast to LCA, LCC refers directly to a projects financial costs and considers the economic sustainability of a project (Alyami & Tighe, 2018). Norris (2001) defines LCC as "Life Cycle Cost compares the cost-effectiveness of alternative investments or business decisions from the perspective of an economic decision maker such as a manufacturing firm or a consumer" (p.118). A completed LCC analysis includes all the costs of a

project throughout its life-cycle and is able to evaluate different project options against each other (Alyami & Tighe, 2018; Shengping et al., 2019). LCC is used widely in the construction industry and can be used to justify decisions according to financial and procurement related issues (Shengping et al., 2019).

3.6.2 The Swedish Transport Administration Climate Calculation Tool

The transport system has a significant impact on the climate throughout emissions from the traffic, but also from construction, operation, and maintenance of civil engineering works (Toller, 2018). STA has developed a climate calculation tool, which is used for calculating the climate impact in terms of energy use and carbon dioxide emissions of the construction projects that STA are responsible for. The climate calculation tool is an approximate method which does not address sustainability as a complete concept, according to Toller (2018) the tool can be used for:

- "Follow-up the climate and energy performance of an object or measure through the establishment of a climate declaration.
- See how different measures affect the total calculation, as part of the project's work with climate and energy efficiency improvements.
- Compare energy use and climate impact from construction and maintenance of alternative solutions (such as alternative routines).
- Follow-up energy use and potential climate impact as a part of results reporting linked to the Swedish Transport Administration objectives.
- Estimate the future energy use and greenhouse gas emissions of several objects, e.g. in a national transport plan.
- Calculated baselines for climate qualification criteria, and for verification of achieved reductions of greenhouse gas emissions." (p.7).

3.6.3 Multi-Criteria Decision Analysis Method

Multi-criteria Decision Analysis (MCDA) is a collection name of different types of methodologies used for decision making. The use of a MCDA method is especially useful when "addressing complex problems featuring high uncertainty conflicting objectives, various forms of data and information, multiple interest and perspectives and the accounting for complex and evolving bio, physical and socio-economic systems" (Kowalski et al., 2009, p. 1065). Because of the MCDA methods ability to address complex problems, it is considered to be additionally suitable for sustainability assessment (Bueno et al., 2015). When considering sustainability assessment, the criteria's used should include somewhat equal addressing of social, economic and environmental sustainability. Both the weighting and identification of the criteria's are essential to be able to measure their impact. Bueno et al. (2015) emphasizes the importance of weighting criteria's when evaluating sustainability transport projects and points out that it is done "in order to measure better their relative impact" (p.638).

Further, Ek et al. (2019) states that "By using MCDA, sustainable alternatives have a better chance of being offered to the client as a choice based on a transparent, structured and to the greatest extent possible, objective evaluation, rather than a subjective and ambiguous evaluation." (p.1090). There exist no standard methods for how the sustainability criteria's should be weighted, neither how the pillars of sustainability should be addressed equally in infrastructure projects, which in turn leads

to that the decision-makers fail in making the weighting open and exact (Bueno et al., 2015; Ek et al., 2019). Due to the lack of standard weighting and consensus in what items to include, the MCDA approach contains bias to some extent. There is a challenge in finding balance between valued weights and assumptions (Bueno et al., 2015).

MCDA can be used in all different stages of the project (Ek et al., 2019). When used in early phases such as client's design and evaluation of tenders, it puts rather high demands on the method used for evaluation. In the traditional tender evaluation of infrastructure projects, it is usually the lowest price tender that is prioritized in the criteria's stated by the client (Ek et al., 2019). This constitutes a barrier for sustainable criteria's since they might not be the cheapest ones. When using the most economically advantageous tender, it could include not only the lowest price but also the most optimal ratio between price and quality where the social, economic and environmental sustainability can be included (Ek et al., 2019). Ek et al. (2019) have shown that MCDA is beneficial to use in the early stages of the procurement, to enable the inclusion of further aspects of sustainability, providing a basis for a tool which considers all sustainability aspects.

3.6.4 Proposed Method based on International Standards for evaluation of Sustainability

Existing international standards provides a general framework for sustainability performance assessment of civil engineering works (Ek et al., 2020). It is preferable to use sustainability performance assessment to make better choices regarding the sustainability of the projects. Ek et al. (2019) highlights the importance of creating a tool that considers the project's whole life-cycle, including both environmental, social, and economic sustainability, at the same time as it follows European standards. However, the international standards do not provide any detailed guidance on how the calculation of the sustainability indicators and their aggregation should be executed (Ek et al., 2020). Ek et al. (2020) proposes a method that can be used to assess the whole life-cycle of civil engineering works, applicable for all stages of the process. Based on European standards, the method calculates and weights different indicators against each other, and in that why different concept designs are compared without affecting each other. The indicators in the method include all aspects of sustainability, and the method is of interest to compare with the already existing climate calculation tool from STA, which only considers the carbon dioxide emissions. By using European standards for developing a method that base on the whole life-cycle of the works, an overall perspective of sustainability is considered. It is preferable to include a sustainability assessment in early phases of construction, and Ek et al. (2020) states that "The possibility to influence the sustainability of a design is larger in the conceptual stage of the design process than in later stages" (p.2).

3.7 Theoretical Context

The theoretical framework has its basis in providing a thorough understanding of how the construction process is carried out as well as introducing sustainability and buildability. Figure 3.4 presents how the sections in the theoretical framework relate to the research questions of the study, where sustainability and buildability constitute the core.

The main roles considered in the construction process are presented in Section 3.2, to provide a theoretical basis for RQ1. In Section 3.6, several of tools and methods for including sustainability and buildability as criteria in the construction process are explained, which is necessary for RQ1. The cornerstone of the research is that the economic aspect of sustainability is somewhat acting as a catalyst for other aspects, especially when looking at business-driven sustainability. It is of interest to

consider how business models and structures relate to sustainability, as well as how this depends on the project delivery method. Thus Section 3.6 can be associated with RQ2, see Figure 3.4.

For enable understanding of RQ3, the theoretical framework has to provide information about how projects can be executed with respect to project delivery methods, Section 3.3, as well as the tools for considering sustainability and buildability, Section 3.6.

The study has taken inspiration from two existing work plans from the RIBA and AIA, Section 3.1. This is necessary to enable for answering and discuss concerning RQ4. When presenting the international work plans that exist within the building sector, the study has chosen to focus on presenting when the actors can be included in the process, see Figure 3.1 and Figure 3.3.

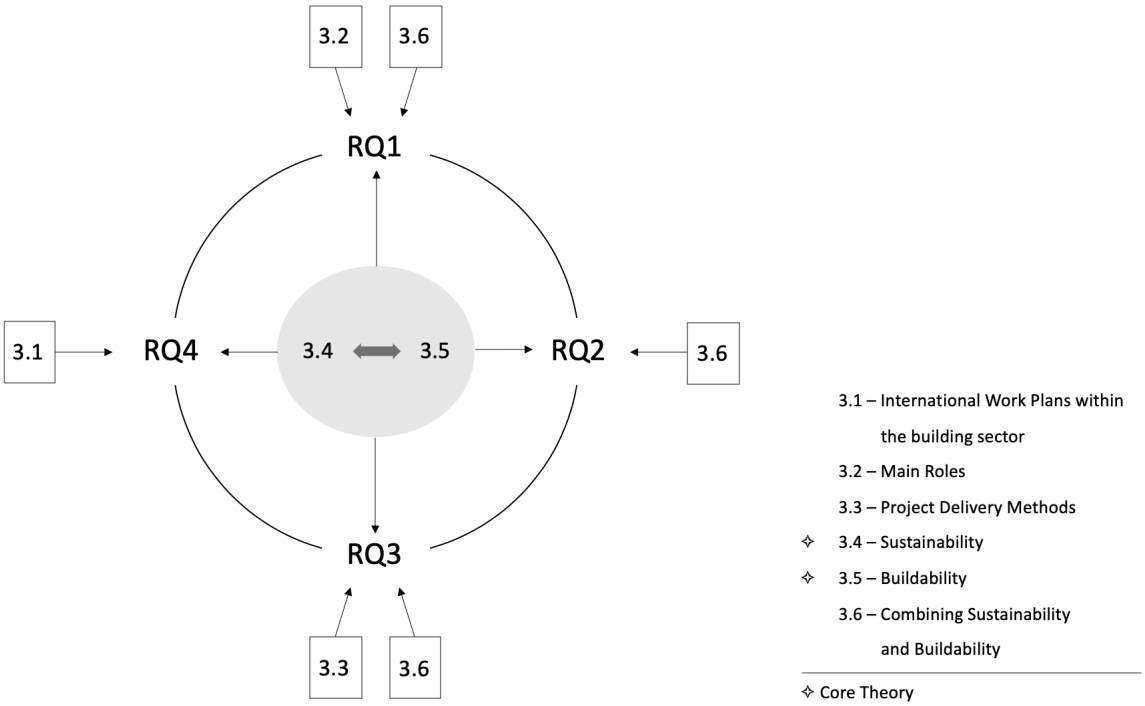


Figure 3.4: Illustration of how the theory relates to the research questions.

4 Empirical study

The purpose of this chapter is to present the information found in the interviews in a fluent text where all data gather under following four different subcategories; *Economy*, *Early Phases*, *Roles and Responsibilities* and *Tools and Driving forces*. The subcategories have evolved during the work by interpreting the empirical data and constitutes its core objectives.

4.1 Economy

For achieving sustainability in the projects, all aspects of sustainability have to be considered (Contractor#2). However, it is commonly found from the interviews that the economic aspect is somewhat the driving force in the beginning. Contractor#2, Client#2, and Structural Engineer#1 all accentuate that economic sustainability is the part of sustainability prioritized in the infrastructure sector and governs when looking at civil engineering works.

> *"Economic sustainability is number one, unless we can make money we cannot keep up with the other parts either."* (Contractor#2)
>
> *"It is always the economic aspect that governs, regardless."* (Client#2)
>
> *"Initially it is very often that the economy governs. 'Do we afford to construct this?' 'How far can we pressure the price?' And then it transfers somewhat to, how the other aspects can be included."* (Structural Engineer#1)

Without economic sustainability, there exists no incentive for making better solutions concerning environmental sustainability. An economical, cost-saving solution can further push the environmental sustainability aspect, although the economy was initially focused (Contractor#2). It is a fact that the climate issue no longer can be disregarded, and according to Contractor#2, the industry is in a transition period. Reducing the carbon dioxide emitted from construction is usually profitable. However, Contractor#2 emphasizes that the driving force for working towards this, in the long run, is to generate cost savings, where the climate calculation tool is a good example.

> *"In that way the costs are lowered. From having a pure cost-driven focus, we have to start working with the environmental aspects, which in turn generates lower costs for us."* (Contractor#2)
>
> *"I would say that economy most often is in the lead ... it is not rare that economic and environmental aspects go hand in hand. If we can win a procurement, for example, it is both cheaper and more profitable from an environmental perspective to keep the existing bridge prior to demolish it and to build a new."* (Structural Engineer#1)

It is necessary to regard the whole life cycle of the bridge. Performing maintenance is a significant source of cost and should be considered thoroughly already during the design phase. Client#2 implies that by considering both buildability and sustainability, the projects will be profitable.

> *"You have to take both sustainability and buildability into consideration because you cannot only creating something that is easy to construct, but that does not last. So you have to all the time study the whole chain of activities and it is then that the Life Cycle Cost enters in a good way, that you make sure to create a construction that is buildable, that you also can inspect and carry out maintenance on and to do these things in the most*

economically and advantageous way as possible. Where productivity is one part, and sustainability with respect to the life span of the constructions is another." (Client#2)

However, there is a problem within the STA today regarding the cost of performing maintenance and constructing new bridges (Client#2). Concerning economic sustainability, it needs to be built with such good quality so that the bridge can stand for at least 120 years. The budget for the new constructions and renovations are unfortunately separated. Client#2, therefore, sees a notable improvement that can be made by the thinking of LCC and have a mutual budget.

"When we get there that we can agree on one wallet, we have come a long way because then we can build the right construction and have the right investment cost and the right maintenance cost" (Client#2)

As it is today, the procurement process is driven by the economy, by other means the lowest price. Client#1 is positive for including new parameters in the procurement process and abandoning the lowest price. However, the need for having economy as a fundamental concept in the procurement will always exist, and thus it will only be possible to lower its impact on the process. One possible solution that Client#1 mentions is to let the price only govern by 50 % and besides that, including more parameters. Client#1 implies that these types of problem-solving methods should be used to a greater extent than done today. Material Supplier#1 agrees with this and means that the economy is the governing factor in the industry today, not only concerning the procurement routes. However, if rating the carbon dioxide concerning cost, the industry would be more prone to consider it (Contractor#1).

"Having a procurement process that is controlled by both carbon dioxide emissions and the lowest Life Cycle Cost price would be the most optimal, so we get sustainability from the design point of view also." (Client#2)

By transferring the focus towards including thorough thinking of carbon dioxide emissions, there will be risks for sub-optimization (Material Supplier#1). There are more aspects of environmental sustainability than only carbon dioxide emissions. Therefore, it is necessary to look for a way to weigh and reward different functional demands as well as a life cycle thinking of the design to achieve a better procurement route. However, Material Supplier#1 emphasizes the risk of creating a process that is too complex, which instead would be hampering.

"There is a risk for sub-optimizing if transferring from economy to only environmental." (Material Supplier#1)

Client#2 thinks that creating a procurement process that is governed by both carbon dioxide emissions and the lowest life cycle price would be the most optimal. The risk with only looking at carbon dioxide emissions is that the material used, most commonly concrete, would be optimized. It would appear in a way that the life span of the structure will be shorter, and the bridge will require maintenance more frequently, resulting in an increased amount of emitted carbon dioxide at the end.

"Because if we only focus on achieving lowest carbon dioxide, then we might end up optimizing concrete and reinforcement so much that we in 20 years have to renovate the bridges, and that is not good. Then we have lost in carbon dioxide anyway. So if we get an optimized construction with respect to both the Life Cycle Cost, by other means the life span of the construction and the carbon dioxide emissions in the beginning, then we control the whole chain. That is what I want as a tool." (Client#2)

However, having carbon dioxide as the base for the tendering process does not go by unopposed. If the transitions when implementing it are not well thought through, there will be complications with doing so (Client#1). At the same time, there is a need to update the procurement process to steer towards more sustainable thinking in the infrastructure sector. Client#1 also emphasizes that the laws for public procurement should be updated to promote long-term work between actors. By having long-term cooperation, the development would be driven forward in a completely different way, which can be seen from the automotive industry where the progress has come further thanks to strategical partners (Client#1).

According to all interviewees, the best solution would be to find a gathered way of weighing the performance requirements and the LCC together. A weighting between economy and carbon dioxide would provide better control, something that requires major political decisions (Contractor#1). In the process of trying to combine economic and environmental sustainability, Structural Engineer#1 highlights that there will be conflicts of aims. It is then essential to know how to solve them and what parameters to follow.

> *"The economy is a major driver in large infrastructure projects, and if you can set a price for carbon dioxide emissions then you can get the most environmentally friendly project."* (Contractor#1)

The most economically advantageous price is another way to handle the procurement process and a way to go from the lowest price (Client#1). It would consider different factors such as choice of method and how to handle environmental issues, which will enable more parameters to influence the process, possibly providing a better solution. With this, the STA sees risks and says that they think it is difficult and could result in an increase in appeals, although Client#1 emphasizes that the public procurement process needs further investigation.

4.2 Early phases

The integration of different roles early in the design phase is, according to several of the interviewees, a key to the successful execution of construction projects concerning both sustainability and buildability. The project delivery method that is used affects how the construction project will be executed. Which method that is preferable to use to enhance buildability and sustainability differ between the interviewees.

According to Client#1, the significant advantage with DB is that contractors are involved in early phases, which enables improved buildability. Client#1 claims that an ideal project delivery method concerning buildability is to combine ECI with DB, which is supported by both Contractor#2 and Client#2.

> *"We believe in that when the contractor is included in the planning stage, in other words in Design-Build projects, it encourages a greater buildability. Because then the contractor, if being active and dedicated to do a good job and earn a lot of money, can be a part and actually affect the planning stage so that it is easy to construct later on."* (Contractor#2)

> *"If the expertise of the contractor is involved in an early phase during the design process of the bridges for example, then they will be able to say 'here we can see that you have made minor mistakes if the reinforcement is put this way it will go much faster for us*

to build' for example, so that you include, the contractor is the expert on how to build and it is their knowledge we have to bring into an early phase in order to find the right productivity and buildability." (Client#2)

The earlier buildability and sustainability are considered in the process; the more right decisions can be made, which will result in better and more optimized projects (Client#2; Contractor#1).

"This means that we should make the documents and that the contractor should build with respect to the documents that we provide, the contractor should by other means not design so much themselves in this case, we will do most. And then we must optimize these factors before the contractor starts. That we make sure that we state the right kind of concrete and steel and so on /.../. Then we have the opportunity to in early phases write in these performance requirements." (Client#2)

In the planning phase, the base for how the project will be executed concerning buildability and sustainability is established (Contractor#1). Criteria and demands are preferable to add to the design parameters in the early phases to promote sustainability and buildability (Contractor#1; Client#2). Structural Engineer#1 implies that dealing with the sustainability and buildability issues in early phases is rather new, but something that the industry tries to implement. Thus, there lays responsibility for the structural engineer to raise the topics early with their client.

"We are working with that now, trying to readjust, to actually be there, and raise the question with our clients early. Have you considered this? Is it possible to do it in another way? Do you have to build exactly this bridge? Is it possible to reduce the amount in some way? Do you have to build at all?". (Structural Engineer#1)

In the early phases, most commonly, the structural engineer establishes the design solutions, even though they might lack the proper knowledge to make the most buildable and sustainable solution.

"The more information you have, the better decisions you can make. But at the same time, everybody knows that it is also in the early phases that you can influence the most, but then we also have the least information." (Structural Engineer#1)

"In the early phase it is most commonly consultants that establishes the design solutions, and they might not have the knowledge about the construction issues, the buildability issues, to the full extent." (Client#1)

A solution to this could be that the client in an early phase demands that the competence should be included in the work of the structural engineers, something that is not done today (Client#1). However, it is essential to underline that it is in the early phases that the possibility to influence the most exists since then their specific aims and goals can characterize the project.

"There is something called 'actuating curve' with project time on the horizontal axis and impact on the vertical axis. At the start there is 100 % and it is possible to impact everything, as the project proceeds the ability to impact will be reduced." (Client#1)

The focus on sustainability is different in the different stages of the construction process. Contractor#2 claims that the overall approach to sustainability is not given until all steps are carried out. Unfortunately, it is a chain without connection. Sometimes it becomes a stick that you hand over rather than collaborating (Contractor#2). If more information is obtained in earlier stages, it will result in that better decisions can be made by the structural engineer. The Structural Engineer#1

claims that it is easier for them as consultants to see what can be changed and improved if there is an established design solution, then there are more facts to work with in comparison to the early phases.

> *"The more information that you have, the better decisions you can make, somewhat. But at the same time, everyone knows that it is also in the early phases that you can make the largest impact, but it is at that time that we also have the least amount of information. So then, it is easy that you somewhat take the decision from what you know, you do not know so much, and because of that, I cannot take so many decisions about it. So somewhere it becomes an exercise of guessing."* (Structural Engineer#1)

When the structural engineer has finished the design proposal, changes to it can be done more easily, for example, concerning which material used (Structural Engineer#1). However, Material Supplier#1 says that it is preferable to include them before the structural engineer forms the design solution.

> *"Generally it is possible to say that the earlier involvement, the better because then it enables for involvement before the design solution is decided with respect to which concrete that should be used, so then you can improve the efficiency throughout the whole chain of activities, everything from choice of concrete to raw material, to concrete, to concrete design, to the configuration of concrete too, so the earlier involvement the better."* (Material Supplier#1)

For including buildability and sustainability in the early phases of the construction process, the industry's education in understanding the importance of the issue is necessary. It is crucial to construct in a smarter way where standardization and grouping of bridges in large projects can be a possible solution. To include buildability and sustainability in the early phases, the client can include parameters regarding this in the specifications and address them as criteria (Client#2).

> *"If the expertise of the contractor is involved in an early phase during the design process of the bridges for example, then they will be able to say 'here we can see that you have done minor mistakes, if the reinforcement is put this way it will go much faster for us to build' for example, so that you include, the contractor is the expert on how to build and it is their knowledge we have to bring into an early phase in order to find the right productivity and buildability. "* (Client#2)

> *"In the best of worlds, it would be preferable to have, in my opinion, an increased climate consideration in the early phase. Since there is a limited amount of impact that the contractor and the consultant can do in the later phases."* (Client#1)

Client#1 puts great value in knowledge experience for achieving good buildability and sustainability in the projects. A possible way of doing so is if the STA procures consultants that undergo the whole process.

> *"It is both a knowledge issue and a permission issue. But with respect to that point of view, it should be a clear advantage if for example, the Swedish Transport Administration procures a consultant that will follow throughout the whole process from beginning to the end and then have demands on that there is experience feedback."*. (Client#1)

4.3 Roles and Responsibilities

Crucial for introducing buildability and sustainability in the early phases of construction is that the actors involved both take their responsibilities and cherishes good trans-boundary relationships. All actors must understand how each other work for the activities to be optimised (Structural Engineer#1). Naturally, a big responsibility lies with the client to choose a project delivery method that enhances this. It could be preferable to use collaborative project delivery methods since those require good relations and open dialogues between the involved actors.

> *"I think that when the client in an early phase establishes the requisites for cooperation, it should also provide the possibility for buildability and sustainability."* (Structural Engineer#1)

The individual responsibility taken by each actor will only have the maximum impact if collaboration across the boundaries of the roles exists. To achieve this, the choice of project delivery method is essential (Client#2). It is in the opinion of Client#2 that there exists certain inertia in the industry that stands in the way of trying new methods, combined with a tendency to try new things on way too large and complex projects. The clients underline that the use of ECI would enhance both sustainability and buildability. Still, it has to be firstly tested on smaller and less complicated projects because it is crucial to understand the means and fundamentals of collaborative methods such as ECI to make them function well.

> *"It is a game between the contractor and the client. The contractor wants to earn as much money as possible, and the client wants to pay as little as possible. Therefore, it becomes a game in between them, and if the rules are not fixed, it becomes extra difficult. So by that reason, these new things should be tested in smaller and less complex projects where the risks are not as big."* (Client#2)

To go with profit in the projects is fundamental for all actors involved. The leading cause for the inertia of trying new project delivery methods is the fear of losing money (Structural Engineer#1; Client#2). A common problem with collaborative methods is that each actor tends to fall back in their old way of working when encountering issues, to save money.

> *"We tend to if things do not really go as we planned it to, fall back into the old patterns and execute the projects in the same way as the time before in order to protect our own business in some way."* (Structural Engineer#1)

According to Client#2, there is a lack of investment in developing the infrastructure industry and that there is a specific responsibility laying with the contractor to enable trying new project delivery methods. In the long run, the contractor companies could benefit from having a separate budget for development. Before the new project delivery methods are fully functioning, some test projects risk going with a shortage. If project managers on the contractor side knew that there existed a buffer for development projects, it would become more attractive to try new methods (Client#2).

> *"There is a need to develop things, and that is where the inertia is, in my opinion. You do not dare to try new things because there is no money for development on the contractor side."* (Client#2)

Contractor#1 believes that there exists a self-responsibility for each actor, already when entering a project, to think if they will be proud of the outcome when finished. Since large infrastructure projects often span over a long period, the regulations and demands may change during construction.

By STA having a long-term perspective in the goals and requirements they put on their contractor, it enables the contractor to dare to invest in education, research, and technology since they know that it will be profitable and rewarded at the end, by becoming more attractive to hire.

> *"Then I know that they will sharpen their demands, and I can invest in seeking for new technical solutions since I know that it will be rewarded by the Swedish Transport Administration. So that long-term perspective is, if I know that there will be governing goals then I can invest in technology and research so that I can meet that demand, then I can contribute by pushing the development."* (Contractor#1)

Cooperation and a close dialogue with the client are vital since it is when the actors come together that the real difference can be made (Contractor#1; Structural Engineer#1). If the project goals coincide across the project boundaries, they automatically become essential for everyone to fulfill, and collaboration is enhanced. Otherwise, it will be a source of conflict, and both buildability and sustainability could be impaired. Structural Engineer#1 opines that both the STA and the contractor acts as clients for the structural engineers, and emphasizes the importance of an open dialogue.

> *"You have to do it together with your client, it is not possible to do it on your own, you have to do it together."* (Contractor#1)

The involved actors in construction projects all have the responsibility to improve buildability and sustainability. According to Client#2, buildability is created by the consultant together with the contractor and material suppliers. By being the specialist, structural engineers often take on an advising role where it is essential to challenge the decisions of the client if there exists a better solution (Structural Engineer#1). It is in the opinion of Structural Engineer#1 that the client also has a responsibility to make sure that the proper requisites and tools for creating more sustainable solutions exist both for them and the contractors. The industry has to understand the integrity of construction and that the work is not linear. From one presumption, other presumptions are created, leading to an iterative working procedure where the one right solution is hard to find directly, if ever at all (Structural Engineer#1).

> *"The client actually works a lot with requisites. That they give the contractors and us both the possibility and space to actually carry out a more sustainable solution at the end."* (Structural Engineer#1)

Choosing the right materials is crucial for both sustainability and buildability. The client is held as main responsible for the choice of material. However, the other actors still have the responsibility to try to steer the work towards sustainable and buildable solutions. As a material supplier, it is vital to work for creating demand but also to stimulate the current needs of the clients (Material Supplier#1). As for the other actors, the economic aspect is of great importance also for the material supplier since it is not profitable to provide services that are not requested by the industry.

> *"If demands are also put on the suppliers, that they have a customer that requests a product that should be more sustainable, then they are forced to create and deliver that, or else they fall off the market."* (Structural Engineer#1)

However, there is a responsibility lying with the material suppliers in trying to make the industry demanding products that are sustainable both in short and long-term perspectives (Material Supplier#1).

> *"It is my task to actively encourage cooperation in the industry to ensure that the*

construction is sustainable in the long-term." (Material Supplier#1)

> *"To cope with these challenges we are forced to optimise, streamline and also to do technology leaps, and the only way to do this is to keep the agenda, keep the short-term and long-term perspective by developing our competence, cooperate to understand that 'A small deterioration from my perspective in my small part of the value chain might result in a major and much better positive effect somewhere else in the value chain, so that we might have to collaborate around'."* (Material Supplier#1)

Structural Engineer#1 accentuates that the role comes with a specific responsibility to implement new working methods as well as new patterns of thoughts to achieve fundamental thinking of sustainability and buildability in the organisation. Structural Engineer#1 believes that it is the responsibility of the leader, not only to show the importance of sustainability and buildability but also to ensure that the opportunities and the right tools are provided to the employees as well as being a culture builder. Structural Engineer#1 believes that if the leader is transparent with its ideas and what is essential, those will reflect in the organisation.

> *"Also to create the requisites, that is also one of my main tasks, to enable for my structural engineers and project managers to go on study visits, invite the contractors and have discussions with them, invite the client to improve the dialogue about how we work and what is valuable to them. That, I guess, is how I can affect and also of course to find the deals where we actually have the opportunity to make an impact."* (Structural Engineer#1)

Contractor#1 thinks that for achieving sustainable and buildable constructions, it is fundamental that the actors work together. Both in-house the companies and across the boundaries of the involved actors. If the actors work closely together, both the planning and execution of the project will be easier to carry out satisfactorily. All companies have their kinds of sustainable directives. However, Contractor#1 emphasizes the importance of communicating knowledge about the company's directives and goals into the epicenter of construction, by other means, the construction site. It is at the construction site where the real difference has to be made, and the goals must be followed by the workers. As part of the top project management, it is essential to follow up on the projects to improve the work. Construction consists of a chain of activities where each activity depends on each other, the people involved as well as different actors.

4.4 Tools and Driving forces

There is a need for implementing a sustainable approach in everyday work by the infrastructure sector being a large construction industry. The STA puts pressure on the industry to start thinking of and actively working on reducing its carbon dioxide emissions by implementing a climate calculation tool. Using penalties and bonuses as incentives for actively considering the effect that construction has on the climate is an exciting way to work and could result in many positive effects (Contractor#1; Contractor#2; Client#2).

> *"The Swedish Transport Administration takes the lead and starts to put forfeits and incentives on how the actors are capable of lowering the carbon dioxide consumption in the projects. Which we think is positive, because then that issue is put in focus."* (Contractor#1)

Client#2 pinpoints the need for clarity, and that the focus has to be on the right things. The climate calculation tool is a way for STA to keep track of how much carbon dioxide a project emits (Client#2). However, there has been insufficient guidelines provided by the STA. A couple of years ago, the STA had a directive on reducing the carbon dioxide emission at each project by 17%. But the measuring of percentage is hard and challenging since it depends much on other factors (Client#2).

> *"To all the time strive after the minimum amount of emissions in each individual situation is probably the best, I think, instead of that every project should reduce their emissions by 17%, because compared to what? We do not really know that."* (Client#2)

For making the climate calculation tool function properly, the employees have to be educated, which Contractor#2 opines that they do at his company. Contractor#2 thinks that the climate calculation tool from STA is a proper tool for achieving its purpose while also encouraging cost savings. Although the climate calculation tool is functioning quite well, Client#2 thinks it could be useful to have a tool that considers both the environmental and the economic aspects of sustainability, for example, combining LCA and LCC in the same tool.

> *"A tool that judges both economic and environmental sustainability would be the most optimal, so you did not have to think. That you do, when you enter the climate calculation tool that you directly receive the economic. 'If we twist it a bit on one parameter here, then the price changes in that way and if we reduce the cost, then the carbon dioxide increases a bit in some way'. So a tool like that would be the absolute most optimum for us as clients"* (Client#2)

However, the industry is far from achieving this, and it requires a tremendous amount of work in combination with an openness for trying new things. The work with establishing such a tool will take a long time and be somewhat a trial and error procedure (Client#2).

The structural engineer has not been working with the climate calculation tool but is familiar with it (Structural Engineer#1). The overall impression is that it is quite well functioning, although it reflects the current situation when using specific input values.

> *"I think that it is more about understanding that it is a snapshot and that it is more of 'today I have this information, and then I get this result and as more information is received the simulation has to be redone' and in that way, the result becomes like you are heading for that direction that was wished for, so I think it functions quite good even though I am not an expert on the climate calculation tool."* (Structural Engineer#1)

One of the biggest challenges when designing a new tool, such as the climate calculation tool, is to consider the right data input. Otherwise, the tool can be hampering rather than improving the work (Client#2). However, the wish for having tools to work with is rather new in the industry, and thus a lot of work is put into finding the right kind of input parameters (Client#2). Therefore the STA continually works together with and supports different research projects, for example, in the concrete industry, to develop more sustainable choices and ensure that the client-side provides the right data inputs and requirements (Client#1). By doing this, the clients force the industry to make more sustainable choices. Recently, more durable concrete has been produced by adding more fly ash as a binder. In turn, this has resulted in the client changing the regulations, and the material suppliers are encouraged to rebuild their factories because they know that using such concrete will be rewarded by the client (Client#1).

> *"Here you see how important it is to have a good collaboration between the client and*

the market and how changing political-legal requirements can put pressure on the market and the industry." (Client#1)

The fact that the construction industry requires a change in its working behavior due to the impaired global environment is commonly found from all interviews. Sweden has come up with a climate policy framework, based on European directives, called Climate Neutral 2045. Per this, different so-called road maps have been established within the construction industry (Material Supplier#1).

"In Sweden we work with, within the limits of fossil-free Sweden with road maps. The cement industry has established one road map, the concrete industry has established one road map, and the construction and infrastructure industry has established one road map. " (Material Supplier#1)

The conversion to working within the limits of these road maps is something that takes time. However, it creates long-term goals and opens up for cooperation between the actors. Material Supplier#1 describes that the concrete industry is working towards the realisation of its road map, and strives to successfully and carefully implement it in the daily work.

It is a long way to go before the goals are reached, and Contractor#1 sees that it is frequent among the clients to have agreed on working with the new Climate Neutral 2045 directives, while they in practice do not. Possibly, this could be because of inadequate knowledge about what the guidelines include and how to work by them (Contractor#1). Commonly, the cross-communication over role boundaries within the organisation fails due to gaps between the top project management and the project managers, leading to that the goals and ambitions of the directives fall in between the chairs (Contractor#1). Contractor#1 implies that the majority of the builders have signed a Climate Neutral 2045, but in some way, they still fail to work following the regulations.

"There is like a gap between the top project management and project management. Municipalities that have signed this but where the project managers within the municipalities are not aware of it, and this does not cope. But then we have a great work in helping each other, and that is quite cool. 'Have you signed the Climate Neutral 2045?' 'Yes, yes we have, how do we achieve it in our project?'." (Contractor#1)

Clear from the interviews is that all actors in the infrastructure industry must work together to achieve the goals and directives of the sustainability work. By having a rather complex value chain with various actors, the construction industry is troubled when it comes to working in collaborative means in practice. The benefit of collaboration between actors is seen since the end of the 20th century, and the new directives enable further implementation. However, this will take time (Material Supplier#1).

"You also have to keep in mind that just because you have made a plan, it will not change over night. There must be a long-term agenda that we work towards and everyone does different things to contribute." (Material Supplier#1)

"The industry is unable to implement these climate changes unless the client and the regulations follow and set goals and use carrot and stick." (Contractor#2)

"The client now goes ahead and puts fines and bonuses on how to lower carbon dioxide consumption in the projects. Which is positive, because then you put that question in focus." (Contractor#1)

When introducing new regulations, the requirements must be set up correctly by the client so that

a good foundation for the contractors to further develop from is established (Client#1; Client#2). Although, according to Structural Engineer#1, the client is somewhat inconsistent with following up if the requirements set up for the climate calculation tool are followed or not at the very end. There is a tendency of the client to be satisfied with the final product, even though it does not meet the demands fully (Structural Engineer#1). Structural Engineer#1 seeks both stricter and more precise requirements from the client-side and thinks that by doing so, the business would be driven a bit longer. Also, Material Supplier#1 and Contractor#2 emphasize that the performance-based demands provided by the client have to be thoroughly designed, preferably so that they stimulate innovation, efficiency, and collaborations.

> *"Fundamentally I believe in that one should have a framework that gives 'carrot and stick' and that stimulates collaboration. One that puts high demands on performance."* (Material Supplier#1)

> *"We see that the Swedish Transport Administration puts demands in the procurement to, in major projects, take for example a climate calculation tool in consideration. And it is really good that function based demands are set /.../ It drives innovation that the different actors has to stretch in order to reach these performance-based demands."* (Material Supplier#1)

> *"With open borders in Europe we become more exposed to concurrence, so I think that it should be good with harder and higher demands. But it cannot be excessive demands. The industry has to manage to, so to say, keep up."* (Structural Engineer#1)

To have as criteria in the projects to use some environmental declaration is a driving force towards sustainable construction projects (Client#1). In the building industry, there exist several standards to follow for classifying projects, such as gold, silver, and bronze classified buildings, indicating the performance of the building concerning, e.g., energy consumption. By having these kinds of classifications, the client demands can be developed further, and it is simplified to construct to fulfill the classifications. This is not as common within the infrastructure industry, although Client#1 implies that it is starting to occur. By having these, further ways of putting demands on the contractors are created.

All the interviewees agree that a regulatory framework that gives 'carrot and sticks' as well as stimulating collaboration and requires high demands on function is necessary for steering towards a sustainable process. Material Supplier#1 believes that by having a framework that provides both incentives for achieving goals, puts high demands on the function of the product as well as stimulates united action trans-boundary the actors is a key for improving both sustainability and buildability in the infrastructure sector.

4.5 Empirical Context

The division of the empirical findings has been made to adapt to the research questions and the theoretical framework. In Figure 4.1, it is illustrated how each section in the empirical findings relates to the research questions, providing the base for analysis and discussion.

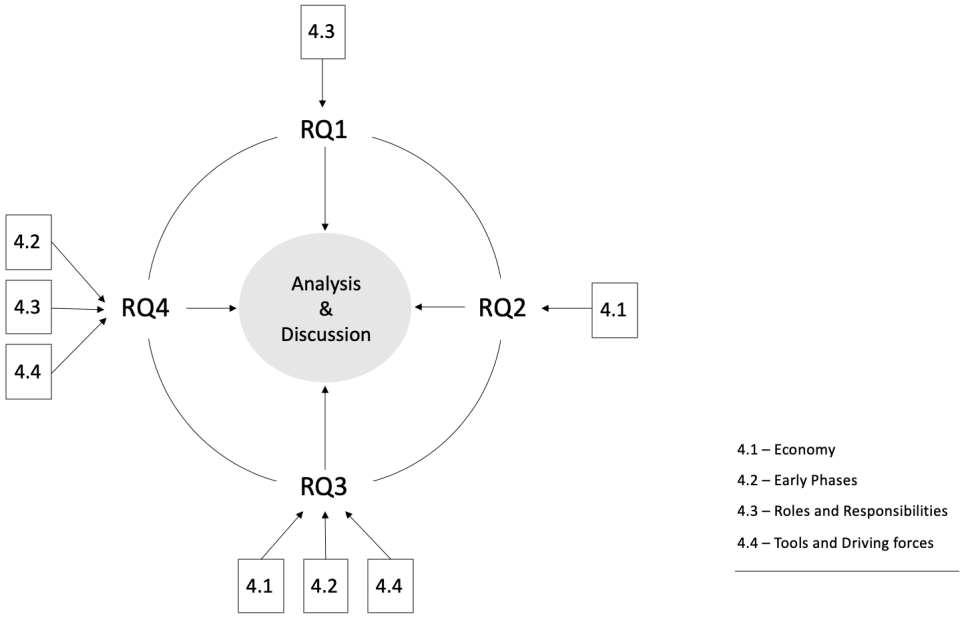


Figure 4.1: The relation between the research questions and the empirical findings, providing the base for analysis and discussion.

5 Analysis

In this chapter, the relations, and contradictions between theory and empirical findings present, to provide an analysis that enables for answering the research questions.

5.1 RQ1 - View of the Top Project Management

By being part of the top project management, there is a particular responsibility to affect and push the development of sustainability and buildability within the organisations. There is a grandness in cherishing good trans-boundary relationships, and Structural Engineer#1 points out the importance of the actors understanding each other to optimise the activities. The theory supports this, with Puddicombe (1997) saying that achieving good collaboration between the involved actors is critical for carrying out successful projects. Client#2 agrees, although emphasizing that there is a certain inertia in the industry for trying new methods and that there is a tendency to fall back into old patterns when making mistakes.

Client#2 is somewhat self-critical to STA's way of trying collaborative project delivery methods on large and complex projects. Alternatively, these collaborative methods should be worked on smaller projects, to learn their characteristics thoroughly before taking on complex projects. Client#2 stresses that there also is a responsibility laying with the contractor to provide a budget for their project managers to try new collaborative project delivery methods, and thereby enabling for start-up projects to go with shortage without risking too much. The fear in the industry of projects going with a deficit is something that inhibits the development and the curiosity rather than improving, supported by Structural Engineer#1 and Client#2.

Even if there is a responsibility with the client to consider sustainable alternatives when it comes to the choice of materials, Material Supplier#1 thinks that it is a responsibility of them also to create a demand for sustainable products, rather then only stimulating the current needs. Per this, Structural Engineer#1 implies that it is their responsibility as advisers, to dare challenge the decisions of the client. However, the client's responsibility is to provide proper tools and precise performance requirements to enable the other actors to offer sustainable solutions.

Both Structural Engineer#1 and Contractor#1 sees that their responsibility, as the top project management, is to enhance sustainability and buildability between other actors as well as within their organisations. This goes hand-in-hand with Clark and Soulsby (2007), who argues that the top project management is the source of influence for the organisations. The top project management's interest is reflected in their actions, which in turn affects the organisation. This is found from all interviews by their engagement and drive to make a change. Contractor#1 emphasizes the importance of getting the knowledge to on-site construction and that it is the top project manager's responsibility to do it.

The top project management tries to take responsibility, and all underlines the need for it. However, the primary responsibility seems to be with the client. The client is somewhat the starting point for change in the industry and thus has to state the precise demands for the other actors to dare invest in research, new technology, and educate their employees. It is commonly perceived that the client is rather slow in seeking new solutions, which might be because of the fear of taking higher risks. As an example of this, Client#1 stresses how STA steps back in enabling withdraw from procurement routes based on only the lowest price, instead involving more sustainable performance requirements in the weighting of tenders, this in fear of a possible increased amount of appeals. The

top project management perceives this inertia from the client-side as hampering for the development of infrastructure projects.

5.2 RQ2 - Driving Aspect of Sustainability

Theory by Dhahri and Omri (2018) implies that the three pillars of sustainability have to coexist and are entirely interrelated. The empirical findings agree with this, stating that it is necessary to consider all aspects of sustainability for the projects to become sustainable. Even-tough all aspects of the term sustainability characterise the sustainability work, it is commonly found that the economic aspect is the driving force for the other. Contractor#2, Client#2, and Structural Engineer#1 especially emphasize this, implying that without economic sustainability, there exist no incentives for making better solutions concerning environmental sustainability. For projects to be profitable, both sustainability and buildability have to be considered. Client#2 emphasizes that even if the economic aspect governs, it is essential to think in terms of life-cycle and LCC. The value of thinking in terms of life-cycle is highlighted in the definition of Supply Chain Sustainability provided by United Nations Global Compact (2015), further supported by Bueno et al. (2015).

Contractor#2 further accentuates that a beneficial economic solution can also push the environmental aspect of sustainability. There is an ongoing change in the industry towards sustainability work driven by the environmental aspect rather than the economy. This is in consent with EuropeanCommission (2015b), who stresses the importance of changing both business models and behaviors so that sustainable use of resources is prioritized. All this is noticeable in the industry, although the economic aspect acts as the foundation.

Interpreted from the empirical findings is that the economic aspect often constitutes the driving force for actors to actuate their business strategies, where some of the sustainability choices are exclusively made for the business to appear correctly, supported by Schaltegger et al. (2012). In compliance with this, Contractor#1 sees a tendency in the industry that particular sustainability work is agreed upon, although it is not implemented in the organisations and provided as actual tools to work with. Regarding this, there is a responsibility with the top project management not to let the work with sustainability only being an ornament for the business model, but to create substantial knowledge to make a difference.

The procurement route today is characterised by the lowest price, which speaks for the economic aspect as the driving force. In compliance with this, Client#1 thinks that the public procurement process has to be updated to distance from the economic aspect and thus promoting long-term work, which would reinforce the industry with faster and more innovative solutions. There is a gathered view in the empirical findings on trying to include several parameters to the procurement route, to decrease the focus on the economy slowly. When trying to go away from only the economic aspect, and to implement other parameters, it is natural that carbon dioxide emissions are the first thing that comes to mind. This is not everything concerning environmental sustainability, and that is important to remember, supported by Material Supplier#1.

The economic aspect appears as the driving force also for the sustainability work within the organisations. Client#2 stresses that STA has separate budgets for maintenance and new constructions, possibly leading to disadvantageous use of economic resources. Even if the STA has money, the money might belong to the wrong budget, with no possibility to lend from the other. Weak organisation structures, in combination with too much focus on the economy, thus become obstacles standing

in the way of the sustainability work.

5.3 RQ3 - Methods and Tools

Allowing all actors to enter the construction process as early as possible facilitates the work with sustainability as well as buildability. Laryea and Watermeyer (2016) confirms this, stating that it is in the early design phase that specialist knowledge has the most significant opportunity to influence the project outcomes. The structural engineers often act as advisers for the client, leading to the importance of including this expertise at the right moment. Structural Engineer#1 points out the difficulties that this advising role brings on when there is not sufficient information available in the early design phases. Therefore, it is of importance to use a project delivery method that advances collaborative choices to include as much information as possible in the early design phases. By doing so, the structural engineers are given room to live out in their advising role, to provide a well thought through proposal. The importance of early involvement is also stressed by Material Supplier#1, who preferably is included before the structural engineer states the design solution.

The choice of project delivery method affects the execution of the projects. For this reason, it is interesting to emphasize how Client#1 sees an advantage in working with DB to improve the buildability of the projects. This is reinforced by Potts and Ankrah (2013); it is more risk-free for the client to work with DB since the contractor comes in early and can plan for construction in the detailed design phase. The benefits for the client to use DB as the project delivery method is highlighted both by Potts and Ankrah (2013) and Client#1. It can be argued that this method would enable for buildability, as a result of only having one entity responsible for operating the construction process, strengthened by Gibson and Walewski (2001). However, Client#1 also believes that the most optimal project delivery method would be the fusion of DB and ECI, confirmed by Contractor#2 and Client#2. The combination of these methods is rarely seen in the industry, although Laan et al. (2010) supports it, stating that ECI in traditional DB projects often is found as beneficial. Eadie and Graham (2014) further emphasizes that being aware of and understanding the project risks becomes better with ECI, and thus buildability improves. It is relevant to accentuate how Contractor#2 sees it as it is the construction process that tends to become a chain without connection, where the phases of construction are somewhat disconnected from each other. Once again, the importance of bringing in expertise and knowledge in the early design phases is observed as a necessity.

There is a limited amount of sustainability assessment tools regarding sustainability and buildability provided in the industry. An existing tool is the climate calculation tool that STA uses in their projects. Even if the tool is created entirely for the consideration of the carbon dioxide emission aspect, it also somehow relates to the economy by bringing on penalties and bonuses, a concept which the industry reacts positively to. For creating a new tool to include both economic and environmental sustainability, Client#2 stresses that it is essential that STA does not forget to focus on adding the correct input data, reinforced by Toller (2018). A tool that emphasizes economic, as well as environmental sustainability, would be optimal. The resent study from Ek et al. (2020) shows that it is possible to consider all sustainability aspects in one tool. The study proposes a method that bases on European standards and has a somewhat equal evaluation of the elements, in contrast to the climate calculation tool by STA, which only considers carbon dioxide emissions. The interviewees stress the importance of having a sustainability assessment tool that considers all aspects of sustainability. Thus, it would be advantageous to follow up on the proposed method of Ek et al. (2020) and to develop it into something that could be used within the infrastructure sector.

Setting the right performance requirements from the beginning is vital, as emphasised by both Client#1 and Client#2. Structural Engineer#1 believes that the client often does not cope with this, and instead tends to be satisfied with the outcome despite what was set from the start. Stricter and more precise performance requirements are desirable to drive the sustainability issue longer. Client#1 believes that changing the regulations is something that STA does to force the industry to work towards more sustainable and buildable solutions. It is interesting how this is supported by Material Supplier#1 and Contractor#2, who also wants to emphasise that directives with long-term goals are advantageous for sustainability and buildability.

To enable the development of the infrastructure sector, is it necessary to consider other sectors as sources of inspiration. It is hard to develop something when only looking in between its borders. Client#1 points out the building sector's way of classifying projects, where you can indicate the performance skill required for each classification, as a good example. By implementing such a system for the infrastructure sector, the client can state specific performance requirements that set off a sustainable and buildable way of working. Creating classifications and creating standards can contribute to a simplified procurement route, where the possibility to appeal to the demands is decreased. Similar to this, Client#2 sees another solution for integrating sustainability and buildability in the use of standardisation and grouping, making construction more efficient. This is brought up by Simonsson (2011), who mentions that there exists both a positive and negative reputation of standardisation. The use of standardisation is an exciting idea, which perhaps should be embraced in the industry.

5.4 RQ4 - Work Plans

AIA's project principle IPD has its fundamentals in the early involvement and collaboration, where it is essential to build trans-boundary relations between the participants. Both IPD and ECI are contractual agreements with their core in preserving the collaboration and trust between actors. However, they are executed in different ways (Ekström, 2019). An ideal project delivery method has been presented as a combination of DB and ECI, since this concept allows the client to keep the traditional project delivery method.

The desirable regulatory framework should be providing carrot and stick, as well as stimulating collaboration and require high demands on performance requirements, to enable for a sustainable process. It is the client's role and responsibility to choose the right project delivery method for each project. Concerning this, a work plan might increase the understanding of how the sustainability work is to be carried out by all actors so that the construction process does not become a chain without connection, which is the tendency today seen by Contractor#2. By trying to create a work plan, similar to RIBA Plan of Work, on how to deal with and organise the process, without deciding on who should do what in each step, a more flexible solution is offered to the actors. It becomes more like a checklist to fill in, which provides a flexible overview of what is left to do. The application of something similar to RIBA Plan of Work to the infrastructure sector seems as easier than trying to implement a new project delivery method such as IPD. The industry might be more prone to a work plan because of its applicability to different project delivery methods. This could help clarify the whole project process since it is repeatedly found from interviews that the process is not linear and that the importance of integration is emphasized.

When learning a new project delivery method, much effort is required from all actors involved. This can be hard since the inertia in the industry is significant, and the liability to change is low. If there

are guidelines, which provides several options to choose between to reach roughly the same outcome, then the optimal combination of choices can be made for each project, leading to slowly changing the industry and implementing a new way of thinking. Large and complex projects characterise the infrastructure sector, and if trying to redo its whole nature and fundamentals, the risk to further complicate the projects is real. The concept of adding a work plan is to simplify and improve the construction process. If the guidelines are too complicated and expect too much knowledge to implement, they will not be used, which leads to that clarity is the basis for trying new things.

6 Discussion

The top project management sees their responsibility in making the infrastructure sector more sustainable, and they notice a need for collaboration and to execute sustainability in practice. The sustainability work has to be embraced fully, to prevent it from becoming only an ornament for the business model. The change towards considering sustainability and buildability in the daily practice of infrastructure construction is in its starting blocks, where significant responsibility potentially lies with the STA, as the most extensive public client of infrastructure works in Sweden. As it is today, the public procurement process emphasizes the lowest price, which constitutes a barrier to new sustainable and innovative solutions.

The empirical findings show that the infrastructure sector should take a shared and mutual responsibility to collaborate and reach higher quality concerning buildability and sustainability. There is a tendency in the industry to fall back into old patterns concerning the execution of projects and which project delivery method used. A work plan, such as the RIBA Plan of Work, could be one of many potential assets to help harmonise the industry regarding who takes the lead in what in collaborative projects. Incentives are necessary, and the interviewees call the attention that they are willing to work with carrot and stick since it helps create financial incentives. However, this is the view of the interviewed top project management, whose positions might give the usefulness of financial incentives a different status. In our opinion, the economy seems to impregnate all choices made during the construction process and constitutes the driving force for working with remaining aspects of sustainability. We posit that there is a fear in the industry to try new, innovative solutions because of the potential economic shortage that might occur when trying new things. Some would evaluate that the risk of being held accountable for creative solutions is real. Therefore, support and financial budgeting in-house organisations are required to promote innovative solutions. To make sustainability choices exclusively based on economic and marketing reasoning might be hard to exclude. However, a change could be promoted by having an open dialogue and good communication between all actors and in-house organisations. Also, if directives are not followed, the power of having forfeits could benefit the development, although this is an issue to be dealt with on political levels.

Carbon dioxide emission is a big part of environmental sustainability, with a tendency to leave other parts of the aspect in its shadows. Constructing new roads and bridges affects nature, making it essential to consider site-specific environmental effects with possible adverse outcomes. Hence, these aspects of environmental sustainability cannot be disregarded, leading to a potential need for rearranging the environmental aspect of sustainability. It might be necessary to make carbon dioxide emissions an independent part, not to risk inadequate consideration of other environmental aspects. To lift carbon dioxide emissions forward and to make it into a category of its own, but remaining a part of the term sustainability, might be an improvement. For this, a work plan could help, where each part of environmental sustainability could be considered separately. In such a way, the other sustainability aspects might not end up in the shadows of either economic sustainability or carbon dioxide emissions. If putting a price on carbon dioxide emissions were to be enabled, that would possibly change the view on sustainability in the infrastructure sector. However, this is a political question beyond the responsibility of the interviewed top project management.

The climate calculation tool provided by STA prepared the industry on how to work with sustainability tools, possibly making it more responsive to new methods. The top project management implies a need for a sustainability performance assessment that considers a comprehensive inclusion of several sustainability aspects, such as the method provided by Ek et al. (2020), and it is interesting how

this underlines by all interviewees. Regarding this distinctive need, it would be advantageous to follow up on the proposed method of Ek et al. (2020). Even though this proposed method meets the wishes found in the interviews, the method requires much knowledge and a thorough understanding of sustainability as a concept to be used properly. If this method develops, it would be required by the top project management that they cope with the development and includes it in their business models, making sure that such a method comes to use. Sustainability is a process with a moving target, always influenced by new research. While society develops more knowledge and capability about sustainability, the understanding and approach to it will move. The industry needs to be open-minded about sustainability and buildability, in combination with high tolerance during the implementation of new tools and methods.

Hopefully, we, as students at the beginning of our careers, can, by this Master's thesis, contribute with new ways of thinking regarding this area of research. The fact that we have limited foreknowledge about the subject could result in the contribution of new viewpoints, or at least highlighting things differently, then if we had more in-depth knowledge. Perhaps, this will assist with new ways of thinking in further work to be executed within the Task Group "Sustainability driven bridge engineering" that this thesis is part of.

7 Conclusion

By processing Chapter 5 and Chapter 6, conclusions that answer the four research questions have been made. To follow the structure of this thesis, as well as to provide a clear conclusion, the research questions are answered as follows;

RQ1: View of the Top Project Management - As expected, the top project management view is that they take responsibility for sustainability and buildability, respectively. However, the weight of collaboration and incentives is emphasized by the top project management for improving the work with sustainability and buildability in infrastructure projects.

RQ2: Driving Aspect of Sustainability - The economic aspect of sustainability is found as the most prominent driving force for sustainability. It is an important aspect that enables the implementation of both sustainability assessment tools and work plans in the infrastructure sector. Economic sustainability constitutes the base for financial incentives, which also is found as necessary.

RQ3: Methods and Tools - Collaborative project delivery methods are preferred in both theory and practice; however, slightly more challenging in the latter. The actors of the infrastructure sector desire a new tool that considers all aspects of sustainability, where the proposed method by Ek et al. (2020) is advantageous to presuppose.

RQ4: Work Plans - It would be preferable to implement a similar work plan to the ones in the building sector to harmonise the infrastructure sector. This is a way to facilitate working with sustainability and buildability and to enhance collaborative working methods.

Final conclusions

Studying the answers of the four research questions shows that the study has resulted in the three main concepts; collaboration, incentives, and work plan. How these concepts relate to each research question is illustrated in Figure 7.1.

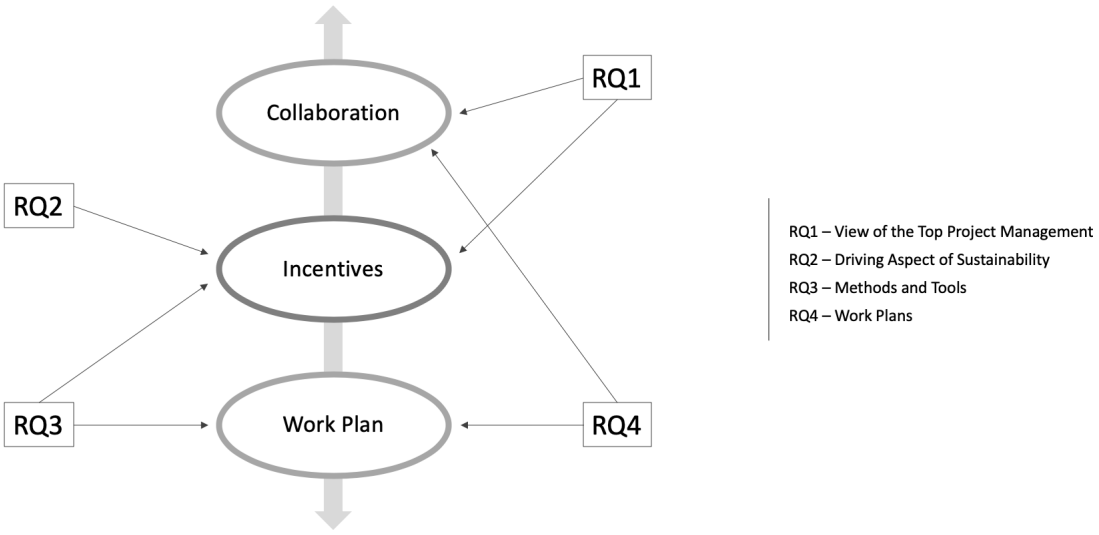


Figure 7.1: How the research questions relate to the three main concepts.

A work plan could contribute to harmonising the construction process and to clearly define roles and

responsibilities for buildability and sustainability in the infrastructure sector. Collaboration is a pre-requisite for successful project deliveries that consider buildability and sustainability, where financial incentives are necessary to stipulate for making it attractive. All three subjects go hand-in-hand and catalyse each other, being somewhat equally crucial to both buildability and sustainability.

7.1 Suggestions for further studies

This mapping has resulted in the need for further studies by being a subject of great actuality in combination with the infrastructure sector needing change. The researches ideas for further studies are presented below.

- Study with a focus on what the infrastructure sector sees as necessary to include in a standard and harmonised work plan.
- A case study where the theory of combining DB and ECI is applied on smaller infrastructure projects in Sweden, to investigate how this combination of methods can be used successfully.
- Implementation of more comprehensive sustainability assessment methods. Furthermore, how these can be used for declaration of sustainability as well as criteria for evaluation of tendering and purchase in general.

References

Adams, S. (1989). Practical buildability. *Butterworths, London*.

af Hällström, A., & Bosch-Sijtsema, P. (2019). *Early contractor involvement in the construction industry: A preliminary literature review*.

AIA. (2007). *Integrated project delivery: A guide*. The American Institute of Architects. http://info.aia.org/siteobjects/files/ipd_guide_2007.pdf

Alyami, Z., & Tighe, S. L. (2018). Incorporating asset value in life cycle cost analysis for transportation infrastructure assets.

Anumba, C., Baugh, C., & Khalfan, M. (2002). Organisational structures to support concurrent engineering in construction. *Industrial Management & Data Systems*.

Baker, J., & Lepech, M. (2009). *Treatment of uncertainties in life cycle assessment*.

BCA. (2004). Code of practice on buildable design. *Building and Construction Authority, Singapore*.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3:2*, 77–101.

Bryman, A., & Bell, E. (2015). *The sage handbook of qualitative data collection* (Fourth Edition). Oxford University Press.

Bueno, P. C., Vassallo, J. M., & Cheung, K. (2015). Sustainability assessment of transport infrastructure projects: A review of existing tools and methods. *Transport reviews*, *35*(5), 622–649.

Clark, E., & Soulsby, A. (2007). Understanding top management and organizational change through demographic and processual analysis. *Journal of Management Studies*, *44*, 932–954.

Compact, U. N. G. (2015). *Supply chain sustainability - a practical guide for continous improvement*. UN Global Compact Office; BSR.

Dhahri, S., & Omri, A. (2018). Entrepreneurship contribution to the three pillars of sustainable development: What does the evidence really say? *World Development*, *106*, 64–77.

Eadie, R., & Graham, M. (2014). Analysing the advantages of early contractor involvement. *International Journal of Procurement Management*.

Edum-Fotwe, F., Thorpe, A., & McCaffer, R. (2001). Information procurement practices of key actors in construction supply chains. *European journal of purchasing & supply management*, *7*(3), 155–164.

Ek, K., Mathern, A., Rempling, R., Karlsson, M., Brinkhoff, P., Norin, M., & Administration, S. T. (2020). A harmonized method for automatable life cycle sustainability performance assessment and comparison of civil engineering works design concepts, In *Beyond 2020, world sustainable built environment conference. iop conference series: Earth and environmental science*, Gothenburg, Sweden, IOP Publishing Ltd, Earth; Environmental Science.

Ek, K., Mathern, A., Rempling, R., Rosén, L., & Claeson-Jonsson, C. (2019). Multi-criteria decision analysis methods to support sustainable infrastructure construction. *IABSE Symposium Guimarães 2019 - Towards a Resilient Built Environment Risk and Asset Management*.

Ekström, D. (2019). *Integrated structural and construction engineering - a study of project team performance in swedish bridge design* (Doctoral dissertation). Chalmers University of Technology.

Ekström, D., Rempling, R., & Plos, M. (2019). Integrated project team performance in early design stages – performance indicators influencing effectiveness in bridge design. *Architectural Engineering and Design Management*.

EuropeanCommission. (2015a). *Resource efficiency in the eu*. Retrieved February 5, 2020, from https://ec.europa.eu/environment/basics/green-economy/efficiency/index_en.htm

EuropeanCommission. (2015b). *Using the economy for a sustainable future*. Retrieved February 5, 2020, from https://ec.europa.eu/environment/basics/green-economy/economy/index_en.htm
Ferguson, I. (1989). *Buildability in practice*. London: Mitchell Publishing Company Limited; 1989.
Flick, U. (2018). *The sage handbook of qualitative data collection*. SAGE Publications Ltd doi: 10.4135/9781526416070.
Forgues, D., & Koskela, L. (2009). The influence of a collaborative procurement approach using integrated design in con- struction on project team performance. *International Journal of Managing Projects in Business*.
Gann, D., & Salter, A. (2000). Innovation in project-based, service- enhanced firms: The construction of complex products and systems. *Research Policy*, *29*, 955–972.
Gibson, G., & Walewski, J. (2001). Project delivery methods and contracting approaches: Assessment and design-build implementation guidance. *The University of Texas at Austin*.
Griffith, A., & Sidwell, S. (1997). Development of constructability concepts, principles and practices. *Engineering, Construction and Architectural Management*, 295–310.
Hayati, K., Latief, Y., & Jaka, S. A. (2019). Risk-based contract management on the design and build construction to minimize disputes in infrastructure projects, In *Iop conference series: Materials science and engineering*. IOP Publishing.
Hemphill, L. M. (2009). Building bridges: A study of coordination in projects. *Doctor of Philosophy, in The University of Michigan*.
Jarkas, A. (2010). Analysis and measurement of buildability factors affecting edge formwork labour productivity. *Journal of Engineering Science and Technology Review*, 142–150.
Jergeas, R., & Put, J. V. D. (2001). Benefits of constructability on construction projects. *Journal of Construction Engineering and Management*, 281–290.
Johansson, R. (2002). Ett explikativt angreppssätt – fallstudiemetodikens utveckling, logiska grund och betydelse i arkitekturforskningen. *Nordic Journal of Architectural Research*, *15*, 19–29.
Kadefors, A. (2002). *Förtroende och samverkan i byggprocessen, förutsättningar och erfarenheter*. Chalmers Tekniska Högskola.
Koçtaş, Ö., & Tek, Ö. B. (2013). Construction supply chains: A proposal to develop a new conceptual model, In *International logistics and supply chain congress*.
Kowalski, K., Stagl, S., Madlener, R., & Omann, I. (2009). Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis. *European Journal for Operational Research*, *197*.
Kvale, S., & Brinkmann, S. (2014). *Den kvalitativa forskningsintervjun* (Volume 3). Studentlitteratur.
Laan, A., Noorderhaven, N., Voordijk, H., & Dewulf, G. (2010). Building trust in construction partnering projects: An exploratory case-study. *Journal of Purchasing & Supply Management*.
Lantz, A. (2007). *Intervjumetodik*. Lund: Studentlitteratur.
Laryea, S., & Watermeyer, R. (2016). Early contractor involvement in framework contracts. *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law*.
Loiseau, E., Junqua, G., P.Roux, & v: Bellon-Maurel. (2012). Environmental assessment of a territory: An overview of existing tools and methods. *Journal of Environmental Management*.
Löwstedt, M., Räisänen, C., & Leiringer, R. (2018). Doing strategy in project-based organizations: Actors and patterns of action. *International Journal of Project Management*, *36*(6), 889–898.
Luth, G. P. (2011). Vdc and the engineering continuum. *Journal of Construction Engineering and Management*, *137*, 906–915.
Malterud, K. (2014). *Kvalitativa metoder i medicinsk forskning : En introduktion* (Third Edition, Translated by Per Larsson). Lund, Studentlitteratur.
Næss, P. (2001). Urban planning and sustainable development. *European Planning Studies*, *9*.

Nam, C., & Tatum, C. (1988). Major characteristics of constructed products and resulting limitations of construction technology. *Construction Management and Economics*, 133–147.

Nations, U. (1987). *Report of the world commission on environment and development: Our common future*.

Nichols, M. (2007). Review of highways agency's major roads programme. *London: Highways Agency*.

Norris, G. A. (2001). Integrating life cycle cost analysis and lca. *The international journal of life cycle assessment*, *6*(2), 118–120.

Olsson, H., & Sörensen, S. (2007). *Forskningsprocessen - kvalitativa och kvantitativa perspektiv* (Andra upplagan). Liber.

Park, J., & Kwak, Y. H. (2017). Design-bid-build (dbb) vs. design-build (db) in the us public transportation projects: The choice and consequences. *International Journal of Project Management*, *35*(3), 280–295.

Potts, K., & Ankrah, N. (2013). *Construction cost management - learning from case studies* (Second Edition). Routledge.

Puddicombe, M. S. (1997). Designers and contractors: Impediments to integration. *Journal of Construction Engineering and Management*, *123*.

Rempling, R., Kurul, E., & Akponanabofa, H. (2019). *Research roadmap for information integration in construction*. International Council for Research and Innovation in Building Construction. CIB General Secretariat.

RIBA. (2013). *Riba plan of work 2013 overview*. Royal Institute of British Architects.

RIBA. (2020). *Riba plan of work 2020 overview*. Royal Institute of British Architects.

Scanlon, J., & Davis, A. (2011). The role of sustainability advisers in developing sustainability outcomes for an infrastructure project: Lessons from the australian urban rail sector. *Impact Assessment and Project Appraisal*, *29*(2), 121–132.

Schaltegger, S., Lüdeke-Freund, F., & Hansen, E. G. (2012). Business cases for sustainability: The role of business model innovation for corporate sustainability. *International journal of innovation and sustainable development*, *6*(2), 95–119.

Shengping, L., Yujie, L., Wei, K. H., & Ruidong, C. (2019). The economics of green buildings: A life cycle cost analysis of non- residential buildings in tropic climates. *Journal of Cleaner Production*.

Simonsson, P. (2011). Buildability of concrete structures, processes, methods and material. *Doctoral Thesis, Division of Structural Engineering, Luleå University of Technology*.

SIS. (2017). *Ss-en 15643-5:2017. sustainability of construction works - sustainability assessment of buildings and civil engineering works - part 5: Framework on specific principles and requirement for civil engineering works*.

Stripple, H., & Erlandsson, M. (2004). *Methods and possibilities for application of life cycle assessment in strategic environmental assessment of transport infrastructures*.

Tatum, C. B. (2011). Core elements of construction engineering knowledge for project and career success. *Journal of Construction Engineering and Management*, *137*, 745–750.

Toller, S. (2018). *Klimatkalkyl-calculating energy use and greenhouse gas emissions of transport infrastructure from a life cycle perspective*.

Trafikverket. (2017). *Vem gör vad av myndigheterna*. Retrieved February 24, 2020, from https://www.trafikverket.se/om-oss/var-verksamhet/trafikverkets-uppdrag/vem-gor-vad-av-myndigheterna-inom-transportomradet//

Trafikverket. (2019). *Tillgänglighet i ett hållbart samhälle*. Retrieved February 20, 2020, from https://www.trafikverket.se/om-oss/vi-gor-sverige-narmare/tillganglighet-i-ett-hallbart-samhalle/

Trafikverket. (2020). *Klimatkrav i planläggning, byggskede, underhåll och på teknisk godkänt järnvägsmateriel, tdok 2015:0480* (4th edition).

Van Marrewijk, M. (2003). Concepts and definitions of csr and corporate sustainability: Between agency and communion. *Journal of business ethics*, *44*(2-3), 95–105.

Wong, F., Lam, P., Chan, E., & Wong, F. (2006). Factors affecting buildability of building designs. *Canadian Journal of Civil Engineering*, *33*, 795–806.

Wood, H. (2010). *Modelling project complexity at the pre construction stage* (Doctoral dissertation). University of Brighton.